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STANDARD REAMERS FOR LOCOMOTIVE WORK.

By COLEMAN SELLERS.

[The following is the address delivered by Mr. Coleman Sellers before the Master Mechanics' Association at its recent convention in Chicago, on the subject of Standard Reamers, as reported by the *Railroad Gazette*:]

Mr. Coleman Sellers said: When appointed to report upon the subject of the taper for reamers for bolts used in locomotive work, and a system of gauges to correct and maintain the standard when worn, I hesitated for some little time before accepting the task. In our own practice taper bolts have not been used in the manner contemplated in the report, but I felt able to consider the subject impartially, and so accepted the task. A mechanical engineer is likely to be interested in what tends toward uniformity in shop practice. As the commission given to me calls for a consideration of the taper of the bolts used in locomotive work, in the first place, therefore, it presupposes that taper bolts are a necessity. This may be perfectly correct. In our own practice we divide bolts into classes, and our rule is in every case where a through bolt, that is bolt and nut can be used, a through bolt must be used. If a through bolt cannot be used, then, if possible use a stud bolt; and if that cannot be used, then as a last resort a tap bolt may be employed. The reason why the tap bolt is put last is because its nut is part and parcel of the machine itself. In the other two cases we have the nut upon the bolt or the nut upon the stud, and

in the third case we have the wear-and-tear of a nut forming part of the machine. Through bolts are of two kinds, loose-fitting and tight-fitting, or "body-bound." Loose fitting bolts which are generally black or unfinished, are put into holes $\frac{1}{16}$ of an inch larger than the bolt itself. It is possible in fastening a machine together, whether part of a machine tool or part of a locomotive, to use black bolts in combination with body-bound bolts, the latter serving as dowel pins to prevent side motion. With body-bound bolts, it is customary among machine builders to use a straight reamer and make a straight hole, and turn the bolt straight to gauge, so that it will fit its place. If the bolt is made perfectly straight and fitted into a reamed hole, it is an unsettled question as to how tight it should fit. In practice, the longer and larger the bolt, the nearer it is made to gauge size. A bolt so sized by gauge, as in a short length, to be a running fit, will seem very tight in a deeper hole. The difference between a tight and a loose fit is somewhere in the neighborhood of the ten-thousandth part of an inch. It is held by many locomotive builders, that the use of straight bolts is objectionable on the score that if they are driven in as tight as they say they should be, there is much difficulty in getting them out; that when they are taken out of a hole into which they have been driven two or three times they become too loose, and there is no means of making them tighter, resulting in their being discarded at the expense of making other larger bolts to be introduced in their place. There is no great difficulty about making two bolts of commercially the same size, but there is a vast difference between absolute accuracy and commercial accuracy. Absolute accuracy is a thing that is not attainable. Mr. Bond, from the Pratt and Whitney Company, who is present, knows this just as well as I do. I know how diligently the Pratt & Whitney Company have labored to approach absolute accuracy in their gauges, and how far they are in their own estimation from reaching that point, although they have reached a wonderful degree of perfection. What we have to strive for, then, is commercial accuracy. What system can we adopt that will enable workmen of limited capacity to do work that shall be commercially accurate? The taper bolt, for certain purposes, presents very decided advantages when considered in this relation. I have said that bolts may be made practically of the same diameter. Holes cannot be made accurately of the same diameter by reamers. Each reamed hole is only an approximation to correctness. We have here (showing) an ordinary fluted reamer.

A reamer is intended to produce a straight hole, but you will all admit that having passed this reamer once through a hole, the reamer must be slightly worn. The next time you pass it through it is a little

Fig. 1.

more dull, and each time it is worse, the hole made by it must become smaller. There have been many attempts to produce a reamer which will be adjustable. Thanks to the gentlemen who are now making such tools a specialty, there now has been added a very useful tool to the machine shop. Here is a reamer made by the Betts Machine

Fig. 2.

Company, of Wilmington. In this the straight cutter blades are made wedge-shape on their back edge, and are seated in wedge-shaped or taper grooves, to match the taper of the blades; these blades can be set to fit a standard gauge.

This will enable us to make and maintain a commercially uniform hole in our work. But the successful use of a reamer of this kind depends upon the drills that precede the reamer, being made as nearly right to size as possible; in other words, that the reamer has as little work given it to do as possible. The less you give a reamer to do the longer it will last and the longer it will maintain its size. The question of tapered bolts involves at once this difficulty, that we have to drill straight holes; then the tapered reamer is obliged to take out all the metal that must be removed in order to convert a straight into a tapered hole. The straight hole reamer is maintained to size longest by taking out the least amount of metal. Hence it follows that the tapered reamer would be the nearest right for durability, which also would take out the least amount of metal. A short reamer like that (see Fig. 1) will answer for a hole of a very considerable depth. It is only necessary that the length of the reamer shall be three or four times its own diameter. The Pratt & Whitney Company has furnished me with reamers made for the Baldwin Locomotive Works. These

are reamers that are to do precisely the work that we now have under consideration. They are to make a tapered hole, but you will observe the difference in lengths between the two. The straight $1\frac{1}{4}$ inch reamer is say 4 inches long in the blades, the taper reamer is say 20 inches long.

Let us now consider the question of amount of the taper. No round piece of iron can go into a round hole in another piece of iron unless it is smaller than the hole into which it is intended to go. If it is in any degree larger it must compress the plug itself, or stretch the material that is around the hole. So if we adopt a tapered bolt we cannot fix upon a certain uniform distance that each and all bolts shall stand out before we begin to drive them. If the material is to be compressed, you will admit that there is a great deal more material capable of being compressed in a piece of large diameter than in one of small diameter. Metal is elastic; as long as we keep within the elastic limit of the metal, we are safe in assuming that it acts like a spring. In the large bolt and in the small one we have springs of different lengths. In the large bolt we have a long spring and in the small one we have a short spring. If we drive a bolt into a large piece of iron, it is the bolt which we compress; therefore the larger the bolt, the more the pressure we can give it to produce the desired result. Therefore if we adopt any fixed taper for our bolts, we will have to use discretion, or go into an elaborate series of experiments, as to how far we should let our bolt-head stand away from the work before we begin to drive it Now I find varying practice obtaining in locomotive establishments. There are some builders of locomotives (I mean connected with railroads) who put the straps upon their stub ends with tapered bolts, but do not use tapered bolts in any other parts of the structure. The Baldwin Works use tapered bolts wherever they require body-bound bolts. They make an universal taper of $\frac{1}{16}$ inch to the foot in diameter. Suppose it is an inch bolt we are dealing with, and an inch bolt 12 inches long, and we started with an inch, and we ran it up to a taper of $\frac{1}{16}$ inch, it would result in this being $\frac{1}{16}$ larger under the head than at the point.

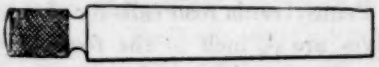
They make all their bolts which are under 9 inches in length $\frac{1}{16}$ inch larger under the head than the name of the bolt. Thus a $\frac{3}{4}$-inch bolt is made $\frac{13}{16}$ under the head, provided that bolt is 9 inches long or under. Anything over 9 inches long is made $\frac{1}{8}$ inch larger under the head and still made a taper of $\frac{1}{16}$ inch to the foot. Most of the bolts

used in locomotives are under 9 inches long. I have been shown bolts 20 to 22 inches long that were made a taper of $\frac{1}{16}$ inch to the foot, and those were the bolts that fastened the saddle and the frame together; practically, however, the great bulk of bolts that are used about locomotives are those which are less than 9 inches in length and come under the category of $\frac{1}{16}$ inches to the foot, and $\frac{1}{16}$ inch larger under the head than the name of the bolt. A locomotive builder now in this city tells me that the specifications of engines submitted to him in many cases name the required tapers for all bolts—some call for $\frac{1}{8}$ inch to the foot. The Pennsylvania road calls for $\frac{3}{32}$ inch to the foot. All Baldwin locomotives are $\frac{1}{16}$ inch to the foot. He tells me that the majority of the specifications, if they do prescribe the taper at all, ask for $\frac{1}{16}$ with the exception of the Pennsylvania. The advantage of the $\frac{1}{16}$ would seem to lie in the fact that a bolt headed in the ordinary manner can be made to fill the requirements, provided it is made of iron $\frac{1}{8}$ inch larger than the name of the bolt. For the purpose of discussing this question at the present time it would be as well for us merely to adopt some taper which I should say might be $\frac{1}{16}$ inch to the foot, and carry that through the system of gauges I propose to show you, so as to enable us to judge whether it is a practical system, and how far we can use it. If we shall decide that bolts should be tapered, for the reason that when a tapered bolt is driven into its place it can be very readily knocked loose, if that tapered bolt, when it is in, proves to be too loose, we have merely to turn out under the head and drive it a little further. These are arguments in favor of the tapered bolts, and show why it is an advantage to use them, their use rendering it easier to repair work that is secured by them than work that has straight bolts. If we adopt a tapered bolt, and let us say with a taper of $\frac{1}{16}$ inch to the foot, it is then well to make up our mind how we are going to make bolts, and bore the taper holes in a commercial manner; in other words, so that it can be brought into what we call the interchangeable system.

No matter what taper is adopted, either by general consent uniform among the shops and the railroads or different in any of them, yet there is always the same need for a system of gauges to carry out the principle in each shop. The Baldwin Locomotive Works, having used the taper system for many years and considering it essential, long ago perfected a system of gauges which seem to me to meet the case. This system may be explained as follows:

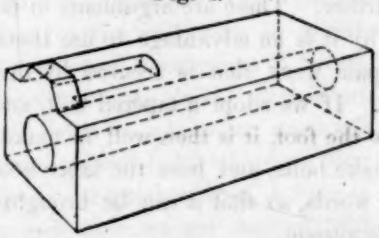
For each diameter of bolt, and for all bolts under 9 inches in length, they keep in their storeroom steel plugs ground to a taper of $\frac{1}{16}$ inches to the foot in length, and each standard plug is made at its largest end exactly $\frac{1}{16}$ inch larger in diameter than the name of the bolt it represents. Thus for a one-inch bolt the standard plug will be on the taper part say 6 inches long, and one end of it will be $1\frac{1}{16}$ inch diameter, and the other end will be $1\frac{1}{32}$ inch in diameter, a convenient milled handle being provided beyond the large end of the gauge, as in Fig. 3.

Fig. 3.



To this standard plug is fitted a ring gauge or female gauge of any convenient external form, which is in length the same as the taper part of the standard plug; so that when the hole and the plug are clean and dry, the one should just fit and fill the other and come flush at the upper end. These plugs and rings are to be retained in the storeroom as standards to try other gauges by. It is stated that the large majority of bolts used on a locomotive and made taper, can on the taper of $\frac{1}{16}$ inch to the foot, be driven home if the size of the bolt and hole is such as will cause the head of the bolt to stand above the top of hole one-eight of an inch, and when such a bolt has been driven home it will have compressed the bolt or stretched the metal into which it has been driven to the amount of ·0065 inch, and the fit will be almost as tight

Fig. 4.



as are car wheels forced on to their axle in the usal manner. The gauges used by the workmen at the turning lathes for bolt work are made of cast-iron similar to the gauge described in connection with the steel plug, but are rectangular, so as to rest well on the lathe bed in a handy position for trial, and on each one of these gauges is cast the representation of one-half of the kind of bolt it is used for, as for example one for hexagon-head bolts, and one for countersunk-head bolts. (See Fig. 4.)

The bench or rather lathe, gauge for an inch bolt may be, say 6 inches long and 2¼ inches square; the same sized casting, in fact, may be used for several sizes of bolts. These lathe gauges are reamed to such a size that the standard plug in the storeroom will be flush with the top of the gauge, precisely as is the standard ring in the storeroom on the same plug. Bolts turned taper must fit this gauge with the head just touching the top of gauge, and without rattle or shake over the length of the gauge. The reamers used for tapering the holes in the shop should be not only long enough to enter the hole drilled and tapered to the required size, but there should be several inches left at the large end to allow for redressing; thus a one-inch reamer should be one-inch in diameter at its small end, at one foot from small end it should be $1\frac{1}{16}$ inches in diameter, and if beyond this it continues at the same taper, say three inches, it should measure $1\frac{5}{64}$ inches in diameter at its largest end. Such a reamer may be reground until its largest diameter has been reduced to the standard size. These reamers are guarded at their upper end by a collar driven on and covering the entire unused part of the reamer, which collar can from time to time be dressed off at the lower end to gauge, to keep the size correct. To adjust the reamers there are kept in the storeroom a set of rings, one for each size of bolt, which are so sized that the standard plug does not enter flush, but stands out one-eight of an inch. It is well, too, to retain in the storeroom reamers not guarded at the large end, which can be used from time to time in retapering the gauges in use at the shop. Figuring or lettering on the gauges should not be on the upper end, as that part in readjusting requires to be turned away.

The same system of gauges for the bolts that are $\frac{1}{16}$ inch larger under the head than the name of the bolt, and which bolts are 9 inches long or under, can be carried out in making the bolts that are ⅛ inch larger under the head and are 9 inches long. The outfit requird, therefore, is for the storeroom: one plug gauge and one female gauge to match for each size of bolt, and for each kind of bolt, whether under or over 9 inches long; one ring or female gauge for the adjustment of the reamers, with the hole as much smaller than the bolt as will give the proper compression, and one standard reamer for the adjustment of the gauges. In the shop the gauges are female for the bolts and the guarded reamers for making the holes.

The taper bolt system calls for the use of two lathes to make each bolt, one to turn the cylindrical apart for the screw thread and to

square up under the head, the other lathe set to a uniform taper, not by the setting over of the head, but by means of some good former attachment, that will insure uniformity of taper regardless of the length of the bolt. In the first lathe the gauges used may with advantage be such as these very fine snap gauges made by the Pratt & Whitney Co. of drop-forged steel, or those made by the Betts Co., of Wilmington Delaware. (Both makes of snap gauges were shown.) With a double ended gauge the cylindrical end of the bolt can be made ready for the screw lathe or the bolt cutter, and with the larger gauge $\frac{1}{16}$ larger, the diameter under the head can be brought to size, and this sized part can be utilized to start the taper in the taper lathe, either starting the cut at that part or setting the tool to a stop screw in the rest at the large diameter, backing off and entering the cut at the small end of the bolt, and turning up toward the head. In practice it is found that the size and taper can be readily hit, and the gauge has very little wear from excessive use and repeated trials. When turned to size the bolt should fit the taper gauge with no shake and the head just touching the end of the lathe. The inspector in the bolt storeroom should also examine the bolts with the taper gauge before putting them into stock. By means of the standards in the toolroom the gauges for the lathe and the taper reamers can be kept to size. There are now to be had very convenient tools arranged for grinding the cutting edges of reamers to any required taper.

It is the practice with some users of taper body-bound bolts to only taper the holes to a depth equal to the thickness of the thinnest piece to be secured. As for example, where the braces from the boiler are attached to the thick frame, they will ream the hole taper through the brace foot and for an equal depth into the frame, and while the bolt is made tapered down to the thread it will not fit the hole anywhere below the taper part of the hole. If a drill $1\frac{3}{64}$ inches diameter be used to drill the hole for an inch bolt, and the drilled hole be reamed out to near $1\frac{1}{16}$ at the top, the taper will be for a depth of 3 inches only; quite enough bearing to hold a foot $1\frac{1}{2}$ inches thick in place.

Having described the system of gauges to you and explained some of the uses and advantages of taper bolts under certain conditions, I do not feel prepared to report in favor of any particular taper for such bolts. The question of uniformity of taper in the body of bolts, while it is of importance as tending to interchangeability, yet involves more important considerations than in the change of the threads used

on the bolts themselves. The taper hole for the bolt in any machine becomes part of the machine. The bolt itself, a movable piece, may be put into such a hole with any one of a dozen kinds of threads cut on its end. The taper that has been already adopted in any shop or on any road requires that all future work shall conform to it.

If the Pennsylvania Railroad and all its branches have adopted $\frac{3}{32}$ it is folly to ask them to change it to $\frac{1}{16}$ inches because their own connections are large enough to make them independent of almost any other corporation, and the need of absolute uniformity in their work would cause them to stick to that particular taper. Any of you having five, six, seven, or two or three hundred locomotives must make up your minds what you will do. When we changed the standard for screw threads, a screw thread was adopted which had a manifest advantage. It is easy to adopt a screw thread. A bolt with any kind of screw thread can be used on any machine. But once having adopted a taper for the body of bolts on a road it is very difficult to make a change, and whether it is wisdom for this Association to say that any particular taper shall be the standard, is a question that I am entirely unable to answer. Therefore, I am unwilling to recommend any taper to you, and only present the facts; but I will say that $\frac{1}{16}$ inch is enough. The less taper you have the less material you have to cut away. But to say that $\frac{1}{16}$ is preferable to $\frac{3}{32}$ is folly because no human being could feel the difference. If a bolt has 5 degrees taper it will set well; if it has 6 or 7 degrees it may jump out. Five degrees is about the angle of friction for iron. Five degrees would be an absurd angle for a taper. Any taper, then, that will hold the bolt when driven in, will answer the purpose. I think that the presentation which I have made, showing you a system of gauges which is already in use by those who have had long experience, may enable you to discuss the matter, so as to arrive at some conclusion as to whether you will adopt a uniform taper or whether you will let things go as they are. Nothing is more desirable than an interchangeable system; and while it is undoubtedly advantageous to make all parts of machines on the interchangeable system, yet in the matter of making holes to size there is a very good illustration of the difficulty enumerated taken from work with which I am familiar. In making turning lathes, the part that the longest resisted this uniformity was the sliding spindle of the dead-head. Spindles may be made very close to size, but not so close that each spindle must be fitted to place in the hole ground out to receive it,

this for the reason that any shake or looseness other than which will permit freedom of motion is detrimental, and it was not until the plan was adopted of arranging conical self-centering clamps to each end of the bearing of the dead-head spindles that such spindles could be made to gauge, and thus added to the list of the interchangeable parts of the machine.

In conclusion, it seems to me that the consideration of the uniformity of taper should be entered upon with caution; but from what I have presented to you as bearing on the facts of the case, you must be quite as well prepared to debate the question as if I had urged the adoption of any particular standard taper. If you do not see fit to consider the question, the system of gauges as used by the Baldwin Locomotive works will enable those who desire to systematize their taper bolt making, and to carry it to a reasonable degree of uniformity in their shops.

ON THE SCREW PROPELLER.

By JAS. N. WARRINGTON, M. E. (Stevens.)

The following pages are confined mainly to a discussion of the principles involved in the action of the screw propeller, and the conditions of maximum efficiency.

In part I the writer has endeavored to present the most advanced views on the subject, with reliable formulæ for design.

Part II contains an original mathematical scheme for the design of a propeller, with a discussion of efficiency.

I.—DISCUSSION OF THE ACTION OF THE SCREW PROPELLER.

The action of the screw propeller was formerly considered to be that of a screw in a nut. The slip was taken as the yield of a solid cylinder of water having a diameter equal to that of the wheel.

A truer conception of this action has come to be accepted at the present day. The late Dr. Froude was the first, I believe, to consider the action as that of a set of oblique surfaces which do not, and in fact should not, drive a solid stream. Had the propeller been developed from the windmill instead of the Archimedian screw, the principles of its action might perhaps have been earlier understood.

If we follow out the blade from the root to the tip, we see that the pitch angle grows smaller, so that the yield of the water is more

nearly in the line of the ship's motion at the tip than near the boss. So far as this is concerned, then, the tip of the blade is the most efficient part.

But fluid friction varies nearly as the square of the velocity. At the periphery, therefore, the frictional loss will be greatest; and we will find that the most efficient part of the blade is at some intermediate point.

Froude finds the pitch angle, or angle between the blade and an athwart-ship plane, to be 45° for maximum efficiency. His discussion* is limited to a flat surface having a rectilinear motion. For such a surface the pressure is

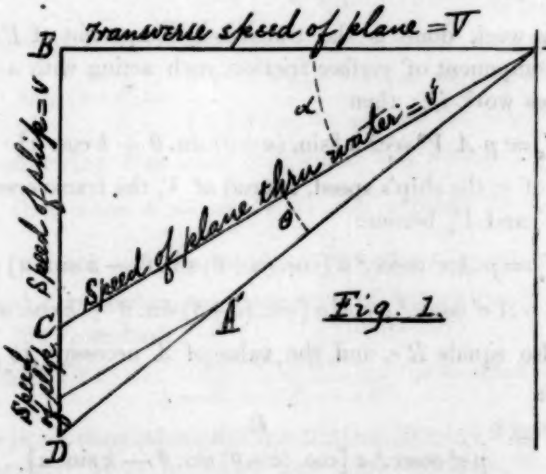
$$P = p\,A\,v^2 \sin.\,\theta \qquad (1)$$

in which p = a constant, A = area of surface, v = velocity of surface through the water, θ = angle between the plane and the line of motion. The value of p is about 1·7. The friction is

$$F = f\,A\,v^2 \qquad (2)$$

in which f = 0·008 for a unit of surface of both face and back of blade.

To investigate the conditions of maximum efficiency let $A\,A^1$ repre-



sent a plane having a transverse velocity $A\,B$. Let $B\,C$ = speed of ship, and $C\,D$ = speed of slip. Then will $A\,C$ represent the motion

* Transactions of the Institution of Naval Architects, 1878, vol. 19, p. 47.

of the plane through the water, both in direction and in velocity; $\frac{D\ C}{B\ D}$ = slip ratio, θ = slip angle, $\alpha + \theta$ = pitch angle. Then by equations (1) and (2) and the figure we have

$$P = p\,A\,V^2 \sec.^2 \alpha \sin. \theta \tag{3}$$

and

$$F = f\,A\,V^2 \sec.^2 \alpha \tag{4}$$

The effect of P in the line of the ship's motion is $P \cos.(\alpha + \theta)$; but from this must be deducted the longitudinal component of the surface friction, which is $F \sin. \alpha$. Thus the net force available for propulsion is $P \cos.(\alpha+\theta) - F \sin. \alpha$. This must equal the ship's resistance, R. Hence we have

$$R = P \cos.(\alpha+\theta) - F \sin. \alpha \tag{5}$$

The effective work done is that employed in overcoming the ship's resistance with the ship's actual speed. Call this work U_v. Then

$$U_v = R\,v = R\,V \tan. \alpha \tag{6}$$

Making the requisite substitutions and putting k for $\frac{f}{p}$ we have

$$U_v = p\,A\,V^3 \sec.^2 \alpha \tan. \alpha\,[\cos.(\alpha+\theta) \sin. \theta - k \sin. \alpha] \tag{7}$$

The gross work done is the transverse component of P plus the transverse component of surface friction, each acting with a speed, V. Call the gross work U_g; then

$$U_g = p\,A\,V^3 \sec.^2 \alpha\,[\sin.(\alpha+\theta) \sin. \theta + k \cos. \alpha] \tag{8}$$

In terms of v, the ship's speed, instead of V, the transverse speed of the plane, U_v and U_g become

$$U_v = p\,A\,v^3 \operatorname{cosec.}^2 \alpha\,[\cos.(\alpha+\theta) \sin. \theta - k \sin. \alpha] \tag{9}$$

$$U_g = p\,A\,v^3 \operatorname{cosec.}^2 \alpha \cot. \alpha\,[\sin.(\alpha+\theta) \sin. \theta + k \cos. \alpha] \tag{10}$$

But U_v also equals $R\,v$, and the value of A necessary to maintain propulsion is

$$A = \frac{R}{p\,v^2 \operatorname{cosec.}^2 \alpha\,[\cos.(\alpha+\theta) \sin. \theta - k \sin. \alpha]} \tag{11}$$

whence

$$U_g = R\,v \cot. \alpha \frac{\sin.(\alpha+\theta) \sin. \theta + k \cos. \alpha}{\cos.(\alpha+\theta) \sin. \theta - k \sin. \alpha} \tag{12}$$

Then the efficiency is

$$E = \frac{U_s}{U_g} = \tan.\ a\ \frac{\cos.\ (a+\theta)\ \sin.\ \theta - k\ \sin.\ a}{\sin.\ (a+\theta)\ \sin.\ \theta + k\ \cos.\ a} \qquad (13)$$

There will be no appreciable error in assuming sin. $\theta = \theta$ and cos. $\theta = 1$. With these substitutions equation (13) becomes

$$E = \tan.\ a\ \frac{\theta\ \cos.\ a - (\theta^2 + k)\ \sin.\ a}{\theta\ \sin.\ a + (\theta^2 + k)\ \cos.\ a}$$

$$= \tan.\ a\ \frac{\theta - (\theta^2+k)\ \tan.\ a}{\theta\ \tan.\ a + (\theta^2+k)} \qquad (14$$

The two differentiations of this equation give respectively the following values of θ and tan. a as the conditions of maximum efficiency:

When θ varies independently, $\theta = \sqrt{k}$.

When tan. a varies independently, tan. $2\ a = \dfrac{\theta}{\theta^2 + k}$

or tan. $a = \sqrt{1 + \left(\theta + \dfrac{k}{\theta}\right)^2} - \left(\theta + \dfrac{k}{\theta}\right)$

and tan. $(a+\theta) = \dfrac{\sqrt{\theta^2 + (\theta^2+k)^2} - (\theta^2+k) + \theta\ \tan.\ \theta}{\theta - \theta\ \tan.\ \theta\ [\sqrt{\theta^2 + (\theta^2+k)^2} - (\theta^2+k)]}$

Substituting $\theta = \sqrt{k}$, we have

$$\tan.\ (a+\theta) = \frac{\sqrt{1 + (2\theta)^2} - 2\theta + \tan.\ \theta}{1 + 2\theta\ \tan.\ \theta - \tan.\ \theta\ \sqrt{1+(2\theta)^2}}$$

Now observing that when θ is small tan. θ does not exceed θ by $\dfrac{1}{3\theta^3}$, so that when $\theta =$ say $\frac{1}{6}$, or just exceeds 10°, the difference between the arc and the tangent is less than $\frac{1}{3^{7}6}$, we may put tan. $\theta = \theta$; and since within the same scale of approximation $\sqrt{1+(2\theta)^2} = 1 + (2\theta)^2$, we have

$$\tan.\ (a+\theta) = \frac{1 - \theta + 2\theta^2}{1 - \theta + 2\theta^2 - 2\theta^3}, \text{ or in effect} = 1.$$

Thus in all cases where the due relation between θ and k, $[\theta = \sqrt{k}]$, is maintained so as to secure maximum efficiency, the actual pitch angle which will give the maximum efficiency is 45°.

Froude shows that the maximum efficiency attainable is 77 per cent. The efficiency of a screw cannot be so great as this, since only one region of the blade can have the most effective pitch angle.

We see from this discussion that small slip does not mean high efficiency. The pitch angle at the centre of effort of the blade should be 45°. Hence, if the blade is wide at the tip, it should have a coarse pitch; and if it is narrow at the tip it should have a fine pitch, the object being to make the most efficient part of the blade do the most work.

The blades should not interfere with each other in their action. The fraction of the circumference occupied by the blade when they are projected on an athwart-ship plane, must not be greater, according to Cotterill*, than 1·18 sin. a cos. a, or more probably less, else the action of the blades will interfere with each other. In this, a is the pitch angle.

It is evident, then, that the action of the screw propeller in its most efficient working, does not involve the sternward projection of a solid stream, and hence all formulæ based upon such an assumption are inapplicable. But at the same time it is to be observed that it is by the sternward projection of the water that the vessel is impelled, and the nearer this approaches a solid stream the less becomes the loss by friction; or, in other words, the frictional loss is smaller, as the blades become shorter and wider, provided they are not so wide as to cause interference of action.

For the common screw of uniform pitch we have the following elementary relations. Let a = pitch angle.

Then $$\text{tan. } a = \frac{\text{pitch}}{\text{circumference}}$$

Speed of wheel = revolutions × pitch.

For the helicoidal area when the screw is limited by planes parallel to each other and perpendicular to the axis, we have the following.

The equations of a helix are† $x = r \cos. \varphi$; $y = r \sin. \varphi$; $z = k r \varphi$ in which r = radius; $k = \frac{\text{pitch}}{\text{circumference}}$; φ = angle at the centre subtended by the projection on a plane perpendicular to the axis.

Let l represent the variable length of the helix; then

$$dl = \sqrt{dx^2 + dy^2 + dz^2} = r\,d\varphi\ \sqrt{\sin.^2\varphi + \cos.^2\varphi + k^2}$$
$$= r\,d\varphi\ \sqrt{1 + k^2}$$

and $$l = r\varphi\sqrt{1 + k^2} + (C_1 = 0)$$

* *Engineering*, vol. xxvii, p. 385.

† Price's Calculus, vol. i, p. 451.

If we let S represent the area we will have approximately,

$$S = \int l\,dr = \varphi \int_{r_2}^{r_1} r\,dr \sqrt{1 + \frac{\text{pitch}^2}{4\,\pi^2\,r^2}}$$

$$= \varphi \int_{r_2}^{r_1} dr\ \sqrt{r^2 + \frac{\text{pitch}^2}{4\,\pi^2}}$$

Integrating

$$S = \varphi\ \left[\frac{r}{2}\sqrt{r^2 + \frac{\text{pitch}^2}{4\,\pi^2}} + \frac{\text{pitch}^2}{8\,\pi^2}\ \text{hyp. log.}\right.$$

$$\left.\left\{r + \sqrt{r^2 + \frac{\text{pitch}^2}{4\,\pi^2}}\right\}\right]_{r_2}^{r_1}$$

r_1 and r_2 being the radii of the periphery and boss respectively. We may put for φ its value in terms of z, the fore and aft length of the blade,

$$\varphi = \frac{z}{kr} = \frac{2\,\pi\,z}{\text{pitch}}$$

For the projection on an athwart-ship plane we have, letting A = the total projected area and N = the number of blades,

$$A = N\varphi \int_{r_2}^{r_1} r\,dr = \frac{N\varphi}{2}\,(r_1^2 - r_2^2) = \frac{N\pi z}{\text{pitch}}\,(r_1^2 - r_2^2)$$

A large majority of the propellers in use at the present day have an increasing pitch, either from the leading to the trailing edge, or from the boss to the periphery. The object of the former is to avoid, or, at any rate, to lessen, the shock at the leading edge, while the purpose of the latter is to move the centre of effort further from the boss to a more efficient part of the blade. I am indebted to Professor R. H. Thurston for the following method of deducing the equation of the curve of the developed screw of axially increasing pitch:—

Let a = angle of initial pitch.
P = initial pitch in feet.
P' = terminal pitch in feet.
$D = P' - P$ = difference of pitches.
C = circumference of screw disk.
K = fraction of circumference occupied by projection of one blade on screw disk.
x and y = coördinates.

As the curvature increases uniformly we have the condition,

$$\frac{dy^2}{dx^2} = \varepsilon \qquad (1)$$

$$\frac{dy}{dx} = \varepsilon x + b \qquad (2)$$

in which ε and b are constants to be determined by values assigned for anterior and posterior pitch.

When $x = o, \frac{dy}{dx} = tan.\ a = b = \frac{P}{C}$

When $x = K\,C, \frac{dy}{dx} = \frac{P'}{C}$

$$a = \frac{P' - P}{K\,C^2} = \frac{D}{K\,C^2}$$

Now equation (2) becomes

$$\frac{dy}{dx} = \frac{D\,x}{K\,C^2} + \frac{P}{C}$$

Integrate and determine constant by the principle that when $x = o$, $y = o$

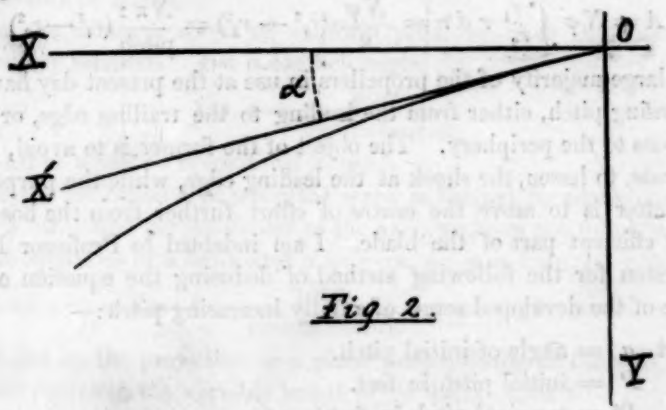


Fig 2.

$$y = \frac{D\,x^2}{2\,K\,C^2} + \frac{P\,x}{C} \qquad (3)$$

Now change the axis of X so that it shall be a tangent to the curve at the origin.

$$y = y' + x'\ sin.\ a\,;\ x = x'\ cos.\ a.$$

Let $l = \sqrt{C^2 + P^2}$; $\sin. a = \frac{P}{l}$; $\cos. a = \frac{C}{l}$

Substituting these values

$$y + \frac{Px}{l} = \frac{D x^2 C^2}{2 K l^2 C^2} + \frac{Px}{l} \quad (4)$$

$$y = \frac{D x^2}{2 K l^2} \quad (5)$$

in which Kl = distance from anterior to posterior edge. Make m = total number of ordinates and n = number of ordinates from o, and

since $$x = \frac{n K l}{m}; \; y = \frac{D K n^2}{2 m^2} \quad (6)$$

In seeking formulæ for the dimensions of the propeller, we may use either the indicated horse power, or the resistance of the vessel. If both are known, it is immaterial which is employed; but if the probable speed, and hence the resistance, is unknown, it becomes necessary to use the indicated horse power. The following formulæ for the diameter and pitch are given by Seaton.*

"The thrust of a propeller has been shown to vary directly as the area of the disc, that is, it varies as the square of the diameter; it has been also shown that the thrust varies as the square of the velocity of flow, that is, as the square of the product of revolutions and pitch. But the speed of the ship varies as the product of the revolutions and pitch, and the indicated horse power should vary as the product of thrust and speed."

Let D be the diameter, and P the pitch of the screw in feet, R the number of revolutions, and IHP the indicated horse power; then

$$\text{Thrust varies as } D^2 \times (R \times P)^2$$

$$\text{IHP varies as Thrust} \times (R \times P) \text{ or as } D^2 \times (R \times P)^3$$

Then $$\text{IHP} = K \times D^2 \times (R \times P)^3.$$

The value of K being substituted, the following formulæ are obtained:

$$\text{Diameter of screw} = 20{,}000 \sqrt{\frac{\text{IHP}}{(P \times R)^3}}$$

or $$\text{Pitch of screw} = \frac{737}{R} \sqrt[3]{\frac{\text{IHP}}{D^2}}$$

* Manual of Marine Engineering, p. 288.

For bluff cargo steamships substitute 17,000 for 20,000, and 660 for 737; while for torpedo boats and fast steam launches use 25,000 in place of 20,000.

PROPELLER WITH GUIDE BLADES.

This form of wheel, although but little used, is not without advantage. In the few cases in which it has been employed, the guide blades have been placed behind the wheel, where they serve to direct the currents into parallel lines, thus absorbing the energy which would otherwise have been lost by lateral slip. The loss of energy by slip is, then, a minimum with this type. Additional friction is introduced with the guide blades, but this is not so great as might be expected; for by the use of guides the diameter may be diminished. We have already seen that the part of the blade near the boss in the common propeller, does not and should not exert much of any thrust, on account of its inefficiency. In the guide blade propeller, on the other hand, this part of the blade has an efficiency nearly the same as that of every other part. This form of wheel may therefore project a *solid stream;* or, in other words, its diameter is a minimum for a given slip and thrust. Thorneycroft has obtained an efficiency of 66 per cent. with wheels of this type.*

The objections to the use of guide blades are three in number, viz.: the additional first cost, the liability to injury by floating obstacles, and the very low efficiency when going astern. Thorneycroft says:

"I consider that there are two kinds of vessels where the guide blade propeller might be used with advantage; they are sea-going vessels which often run in ballast, and, consequently, in their light trim, do not properly immerse a common propeller, and the other vessels for navigation where the draught of water is limited and necessitates the use of paddles or guide blades. In this case it would appear that the guide blade propeller may be more advantageously used than the paddle where high speed is required, owing to the reduction in the weight of the machinery, consequent upon the increased number of revolutions that may be used, at the same time retaining the light draught due to the paddle wheel, and having the further advantage of not increasing the extreme width of the vessel, which is an important feature in inland navigation."

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*Engineering, vol. xxxv, p. 461.

II.

Problem:—Given a vessel with a certain resistance; required the most efficient instrument of propulsion.

This is the problem of marine propulsion stated in its most general form; limited to the screw propeller, it becomes the subject of the following pages. That it remains unsolved is not due to lack of careful thought by talented men, for many able engineers have given it their best efforts. The uncertain nature of the conditions involved renders an exact solution impossible; and the variation of these conditions with the form and surface of the hull, reduces a general formula to a mere guess. But where theory has failed, experiment has in part succeeded, and it is quite probable that a large number of the propellers now in use, have an efficiency which approaches closely to the maximum.

The need of theoretical knowledge is still much felt however. The present propeller blade is, so far as shape is concerned, the result of much paring. It has come to have an increasing pitch, either axially or radially; frequently both. Sometimes the blade is inclined backward; again it is perpendicular to the shaft; the leading, or some other, corner is cut away; and it has many peculiarities such as the myriad inventor has seen fit to impose. But it has no definite mathematical relations with the work it has to do. Its efficiency cannot be analyzed so as to determine its various losses; and hence, time and effort are often wasted in the endeavor to diminish that which, it may be, is already so small as to be almost a minimum.

In the following discussion I have endeavored first to determine the shape of the blade by established principles, and then having given the resistance of the vessel and certain mathematical properties of the blade, to find the dimensions of the wheel. The judgment of the designer must, of course, always be relied upon; for there are too many variable quantities involved to admit of a mathematical maximum. I have chosen to trace the problem in its logical order, beginning with the resistance of the ship rather than with the indicated horse power, because of the more direct relation existing between the former quantity and the dimensions of the propeller. Since the resistance can in most cases be calculated when the indicated horse power is known, no difficulty exists should the latter quantity be given.

My method of treatment is then as follows:

1. Find the shape of a blade such that each particle of water shall

glide upon it without shock and be uniformly accelerated in the line of the shaft.

2. Find by experiment the relation between the acceleration and the intensity of pressure on the projected area of the wheel, this projected area to be upon a plane perpendicular to the axis. Then having assumed the slip and knowing the total resistance we can find the amount of this projected area and also, as will be seen, the diameter.

3. Find an expression for the efficiency; also expressions for the loss of energy by friction, by slip, and by edge-way resistance.

4. Analyze the loss by slip, separating it into its lateral and longitudidal components.

5. Find an expression for the loss of energy by the friction of guide blades. Then we may ascertain the efficiency of the guide blade propeller.

I will first consider the

PROPELLER WITHOUT GUIDE BLADES.

"The fundamental principle on which all propellers act, is that the reaction caused by projecting a mass of water in one direction produces motion of the ship in the opposite direction."*

It is clear then that our propeller is simply a sort of pump outside of the vessel, the sole duty of which is to give motion to the water. In order to avoid shock, this motion should be produced gradually. Further, it is clear that as the water passes across the blade, its velocity relative thereto remains constant; for the blade effects only the *direction* of the flow, and not its relative velocity. The following problem presents itself:—

Required the equation of the curve which a particle will describe, having a constant velocity in its path and a uniformly accelerated motion in the direction of X.

The following nomenclature will be observed. Units are foot, second and pound:

V_0 = velocity of water in direction parallel to axis at the leading edge of the blade; equal, if there be no following current, to the velocity of the ship.

V_1 = velocity of water in direction parallel to axis at the trailing edge.

* Manual of Marine Engineering, Seaton, p. 272.

v_0 = whirling velocity of water relative to blade at leading edge; equal to the linear velocity in rotation of the corresponding point of the blade. Varies as radius and equals $2\pi r n$.

r = variable radius of wheel.

r_1 and r_2 = radii of periphery and boss.

l_1 = breadth of blade.

S = area of surface of blade.

A = projected area of blades upon an athwart-ship plane.

p = intensity of pressure upon this area.

n = revolutions of wheel per second.

R = resistance of vessel in pounds.

f = acceleration in direction of axis.

$V_1 - V_0 = G$ = slip in direction of axis.

$\sqrt{V_0^2 + v_0^2}$ = resultant relative velocity of water.

= velocity of any point of blade.

Take the origin of coördinates at the leading edge, and let x be parallel to the shaft.

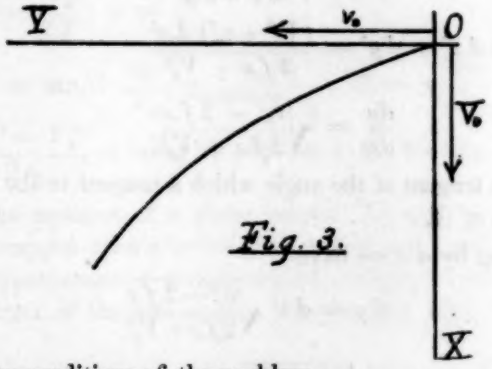


Fig. 3.

Then by the conditions of the problem

$$\frac{d\,x^2}{d\,t^2} = f \text{ and } \frac{d\,x^2}{d\,t^2} + \frac{d\,y^2}{d\,t^2} = \frac{d\,l^2}{d\,t^2} = V_0^2 + v_0^2$$

From the former we have by integration

$$\frac{dx}{d\,t} = f\,t + (C_1 = V_0)$$

and

$$x = \tfrac{1}{2} f t^2 + V_0 t + (C_2 = o)$$

whence

$$t = \frac{1}{f}\left[\sqrt{V_0^2 + 2fx} - V_0\right]$$

And from the second condition we have

$$\frac{dl}{dt} = \sqrt{V_0^2 + v_0^2}$$

$$l = t\sqrt{V_0^2 + v_0^2} + (C_3 = o)$$

whence $$t = \frac{l}{\sqrt{V_0^2 + v_0^2}}$$

Equating the values of t gives

$$\frac{l}{\sqrt{V_0^2 + v_0^2}} = \frac{1}{f}\left[\sqrt{V_0^2 + 2fx} - V_0\right]$$

or $$l = \frac{\sqrt{V_0^2 + v_0^2}}{f}\left[\sqrt{V_0^2 + 2fx} - V_0\right] \qquad (1)$$

an expression for the length of the arc. Now to find the equation of the curve in terms of x and y, differentiate (1) and we have

$$dl = \frac{\sqrt{V_0^2 + v_0^2}}{\sqrt{2fx + V_0^2}}\, dx$$

But $$dl = \sqrt{dx^2 + dy^2}$$

$$\therefore \quad dx^2 + dy^2 = \frac{(V_0^2 + v_0^2)\, dx^2}{2fx + V_0^2}$$

and $$\frac{dy}{dx} = \sqrt{\frac{v_0^2 - 2fx}{2fx + V_0^2}}$$

This is the tangent of the angle which a tangent to the curve makes with the axis of X.

Multiplying by dx we have

$$dy = dx\sqrt{\frac{v_0^2 - 2fx}{2fx + V_0^2}}$$

To integrate this let $\sqrt{\frac{v_0^2 - 2fx}{2fx + V_0^2}} = X.$

Then $$x = \frac{v_0^2 - V_0^2 X^2}{2f(X^2 + 1)}$$

and $$dx = -\frac{v_0^2 + V_0^2}{f} \cdot \frac{X\, dX}{(X^2 + 1)^2}$$

$$\therefore \quad dy = -\frac{V_0^2 + v_0^2}{f} \cdot \frac{X^2\, dX}{(X^2 + 1)^2}$$

By formula of reduction (D) we have

$$\int X^2 (X^2+1)^{-2}\, dX = \tfrac{1}{2} X^3 (X^2+1)^{-1} - \tfrac{1}{2}\int X^2 (X^2+1)^{-1}\, dX$$
$$= \tfrac{1}{2}\left[\frac{X^3}{X^2+1} - X \tan.^{-1} X - K\right]$$

in which K is the constant of integration. We have then

$$y = -\frac{V_0^2 + v_0^2}{2f}\left[\frac{X^3}{X^2+1} - X + \tan.^{-1} X = K\right]$$

For $x = o$, $y = o$, and $X = \frac{v_0}{V_0}$: whence

$$K = \tan.^{-1}\frac{v_0}{V_0} - \frac{v_0 V_0}{V_0^2 + v_0^2}$$

and this value substituted in the preceding equation will give us the equation required. A simpler form, and one more convenient for use, is the following:

$$y = (H+h)(K - \tan.^{-1} X) + X(H+x) \qquad (2)$$

in which $H = \frac{V_0^2}{2f}$; $h = \frac{v_0^2}{2f}$

$$K = \tan.^{-1}\frac{v_0}{V_0} - \frac{v_0 V_0}{V_0^2 + v_0^2};\ X = \sqrt{\frac{h-x}{x+H}}$$

and $f = \frac{V_1^2 - V_0^2}{2x_1}$, x_1 being the abscissa to the trailing edge.

This is the equation of a plane curve. To apply it to a propeller it must be wrapped upon a cylindrical surface and used as a directrix, just as the hypothenuse of a right-angled triangle, so wrapped, is used as the directrix of the *true screw*. The leading edge may have any shape.

AREA OF THE BLADE.

While f remains constant in equation (2), it may vary with the radius. The slip, G, may also vary with r, although constant in the equation of the curve.

We will take four cases.

A general approximate expression for the area will be

$$S = \int_{r_2}^{r_1} l_1\, dr$$

CASE 1.—*f and G constant.*

By equation (1) we find

$$l_1 = \frac{\sqrt{V_0^2 + v_0^2}}{f}\left[\sqrt{V_0^2 + 2fx_1} - V_0\right]$$

in which x_1 is the abscissa to the trailing edge for a breadth of blade, l_1.

But $$2fx_1 = V_1^2 - V_0^2$$

Hence $$l_1 = \frac{V_1 - V_0}{f}\sqrt{V_0^2 + v_0^2}$$

Substituting we have

$$S = \frac{V_1 - V_0}{f}\int_{r_2}^{r_1} dr\sqrt{V_0^2 + (2\pi nr)^2}$$

$$= \frac{2\pi nG}{f}\int_{r_2}^{r_1} dr\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}$$

Integrating

$$S = \frac{\pi nG}{f}\left[r\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2} + \frac{V_0^2}{4\pi^2 n^2}\text{ hyp. log. }\left(r + \sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\right)\right]_{r_2}^{r_1}$$

CASE 2.—$f = m\sqrt{V_0^2 + v_0^2}$; *G constant.*

These assumptions would probably be very suitable for a guide blade propeller. They give us

$$l_1 = \frac{G}{m} = \text{constant}$$

Hence $$S = \int_{r_2}^{r_1} l_1\, dr = l_1(r_1 - r_2)$$

CASE 3.—$f = m\sqrt{V_0^2 + v_0^2}$; $G = k\sqrt{V_0^2 + v_0^2}$.

By thus assuming the slip to vary from the boss to the periphery, we obtain an effect similar to that obtained by increasing the pitch radially in the common propeller.

In this case $$l_1 = \frac{k}{m}\sqrt{V_0^2 + v_0^2}$$

and

$$S = \frac{2\pi nk}{m}\int_{r_2}^{r_1} dr\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2} = \frac{\pi nk}{m}\left[r\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\right.$$

$$\left. + \frac{V_0^2}{4\pi^2 n^2}\text{ hyp. log. }\left(r + \sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\right)\right]_{r_2}^{r_1}$$

in which m and k are constants to be found, either from practice or by experiment.

In the case of very high speed vessels, as torpedo boats, or of large ships where practical considerations relative to the strength of the blade determine, in great measure, its proportions, it will probably be desirable to avoid the wide tipped blade to which the last set of assumptions will lead. Let us then assume f to vary as the square of the velocity and we will have

CASE 4.—$f = m(V_0^2 + v_0^2)$; $G = k\sqrt{V_0^2 + v_0^2}$.

$$\text{Then } l_1 = \frac{k}{m} = \text{constant},$$

$$\text{and } S = l_1(r_1 - r_2).$$

The conditions of this case are favorable to high efficiency, since the centre of effort is well out toward the periphery at an efficient part, and yet the tip of the blade is not so wide as to cause undue loss by friction.

DISCUSSION OF PROPERTIES OF BLADE.

If f and G are taken constant, then will the fore and aft length of the blade, x_1, be constant also; for we have

$$x_1 = \frac{V_1^2 - V_0^2}{2f}.$$

If $f = m\sqrt{V_0^2 + v_0^2}$ and G remains constant, then

$$x_1 = \frac{V_1^2 - V_0^2}{2m\sqrt{V_0^2 + (2\pi n r)^2}}.$$

If $f = m\sqrt{V_0^2 + v_0^2}$ and G also varies with r so as to equal $k\sqrt{V_0^2 + v_0^2}$, then

$$x_1 = \frac{k}{m}\left[\frac{k}{2}\sqrt{V_0^2 + (2\pi n r)^2} + V_0\right].$$

Lastly, if $f = m(V_0^2 \times v_0^2)$ and $G = k\sqrt{V_0^2 + v_0^2}$ then

$$x_1 = \frac{k^2}{2m} + \frac{V_0 k}{m\sqrt{V_0^2 + (2\pi n r)^2}}.$$

In the side vertical projection of the blade we may draw either the leading or the trailing edge, and then by one of the above equations, find the other edge.

We will now consider the intensity of pressure upon the projected area.

Let M = mass of water acted upon per unit of projected area; p = pressure thereon. Then $p = Mf$.

M necessarily varies as $\sqrt{V_0^2 + v_0^2}$.

Then for f constant; $p \propto \sqrt{V_0^2 + v_0^2}$.

Then for $f = m\sqrt{V_0^2 + v_0^2}$; $p \propto (V_0^2 + v_0^2)$.

Then for $f = m(V_0^2 + v_0^2)$; $p \propto (V_0^2 + v_0^2)^{\frac{3}{2}}$.

We may find the radius, $\bar{r}$, to the point of mean intensity of pressure, thus:

$$\bar{r}\int p\,dr = \int p\,r\,dr.$$

For $p = p_1\sqrt{V_0^2 + v_0^2}$ this becomes

$$\bar{r} = \frac{p_1\int r\,dr\sqrt{V_0^2 + (2\pi n r)^2}}{p_1\int dr\sqrt{V_0^2 + (2\pi n r)^2}}$$

$$= \frac{\left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}}}{12\pi^3 n^3\left\{ r\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2} + \frac{V_0^2}{4\pi^2 n^2}\text{ hyp. log.}\left(r + \sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\right)\right\}}\Bigg]_{r^2}^{r^1}$$

For $p = p_1(V_0^2 + v_0^2)$

$$\bar{r} = \frac{\int r\,dr\left(V_0^2 + (2\pi n r)^2\right)}{\int dr\left(V_0^2 + (2\pi n r)^2\right)}$$

$$= \frac{\frac{1}{2}V_0^2 r + \pi^2 n^2 r^3}{V_0^2 + \frac{4}{3}\pi^2 n^2 r^2}\Bigg]_{r^2}^{r^1}$$

For $p = p_1(V_0^2 + v_0^2)^{\frac{3}{2}}$

$$\bar{r} = \frac{\int r\,dr\left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}}}{\int dr\left(V_0^2 + (2\pi n r)^2\right)^{\frac{5}{2}}}$$

$$= \frac{\left(V_0^2 + (2\pi n r)^2\right)^{\frac{5}{2}}}{20\pi^2 n^2 \left\{ \frac{r}{4}\left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}} + \frac{3}{4}\pi n V_0^2 \left(r\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2} - \frac{V_0^2}{4\pi^2 n^2} \text{ hyp. log.} \left(r + \sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2} \right) \right) \right\}} \Bigg\}_{r^2}^{r^1}$$

This point of mean intensity is not to be confounded with the centre of effort. The position of the latter depends upon the distribution of the area, and it will lie beyond or within the point of mean intensity according as the projected width is greater beyond or within. I have not been able to find the radius to the centre of effort because I have no expression for the projected area, the terms involved becoming very unwieldy. This radius must therefore be found from the drawing by an approximate calculation. Calling it $\bar{r}$ we will have $\frac{r}{r_1} = a = a$ constant which will differ for each rate of variation of f and G.

TO FIND THE DIAMETER.

Let p' = the intensity of pressure, or thrust, upon the projected area at the centre of effort; then

$$p' A = R; \quad A = \frac{R}{p'}.$$

In this expression R is the only known quantity. A is sought, hence we must find a value for for p'.

Let f' = acceleration at the centre of effort; then

$$p' = Mf'$$

Now since M varies as $\sqrt{V_0^2 + v_0^2}$, let it equal $\beta\sqrt{V_0^2 + v_0^2}$; then

$$p' = f'\beta\sqrt{V_0^2 + (2\pi n)^2 (a r)_1)^2}$$

in which $(a r_1)$ is the radius to the centre of effort.

If $f = m(V_0^2 + v_0^2)$ then

$$p' = m\beta\left(V_0^2 + (2\pi n)^2 (a r_1)^2\right)^{\frac{1}{2}}$$

To find p', therefore, we must first assume a value for r_1.

Using this value of p' we may find the value of A. If, now, we

make the area of the athwart-ship projection in our drawing, equal to A, we can measure the radius; for the *width* of the blade is fixed by previous assumptions of f and G.

If this value of the radius found from the drawing, differs from that assumed in the formula for p_1, we must find another value for p', using a value of r_1 intermediate between the first assumption and the graphic value. This will give another value for A, and on the drawing, a more closely approximate value for r_1. Thus by trial we can arrive at the correct value for the radius. In the formula for p', the constant β is to be found by experiment, its value being

$$\beta = \frac{p'}{f\sqrt{V_0^2 + (2\pi n)^2 (a r_1)^2}} \text{ in which}$$

p' is the experimental quantity.

If the projected area and the radius to the centre of effort were known in terms of r_1 we could find the exact value of r_1 by the equation $A = \frac{R}{p'}$.

We may however construct such a formula, introducing a constant to be afterward determined. Take the fourth case, in which $f = m(V_0^2 + v_0^2)$ and $G = k\sqrt{V_0^2 + v_0^2}$. In this case we may assume A to be directly proportional to r_1 While this is not exactly true, it will be approximately so within modern limits in practice, and for extreme cases we may find other values for our constant. Further, A will be very nearly proportional to the breadth of the blade into the sine of the angle which its leading edge makes with the axis; that is, to l_1 sin. $\left(\text{tan.}^{-1}\frac{v_0}{V_0}\right)$. Hence we may write

$$r_1 l_1 \text{ sin. } \left(\text{tan.}^{-1}\frac{v_0}{V}\right) = \text{constant} \times \frac{R}{p'}$$

or since $l_1 = \frac{k}{m}$, and sin. $\left(\text{tan.}^{-1}\frac{v}{V}\right) = \frac{v_0}{\sqrt{V_0^2 + v_0^2}}$

$$\frac{r_1 k v_0}{m\sqrt{V_0^2 + v_0^2}} = \text{constant} \times \frac{R}{m\beta(V_0^2 + v_0^2)^{\frac{1}{2}}}.$$

Taking v_0 at the radius to the center of effort which is $a r_1$, we have

$$2\pi n a k r_1^2 = \text{constant} \times \frac{R}{\beta(V_0^2 + (2\pi n a r_1)^2)}.$$

Letting φ represent the combined constants we have

$$r_1^2 = \varphi \frac{R}{n\,k\,(V_0^2 + (2\pi n a r_1)^2}$$

whence

$$r_1 = \sqrt{\frac{V_0^2}{(8\pi n a)^2}} \left\{ \sqrt{1 + \varphi \frac{16\,R\,n\,\pi^2 a^2}{V_0^4\,k}} - 1 \right\} \quad (3)$$

which is the formula required.

The constant φ will depend upon the number of blades, being twice as great for two blades as for four.

The value of φ is found by substituting experimental data in the formula,

$$\varphi = \frac{n\,k\,r_1^2\,(V_0^2 + (2\pi n a r_1)^2)}{R}$$

The method of laying down the blade is as follows: Fix the position of the leading edge. By means of the formula for x_1 find the side vertical projection of the trailing edge. By means of equation (2) find values for y_1 and lay down the athwart-ship projection of the trailing edge. In constructing the cross section of the blade at any radius use equation (2) giving f its value corresponding to the radius. It is to be observed that equation (2) is for a *plane* curve and the values of y must be measured on the arc and projected back.

Having the athwart-ship projection of both the leading and trailing edge we may take the radius r_1, such that the included area shall equal the required area, viz.: A. If r_1 has been already found by equation (3) the labor of measuring the area is avoided.

In the preceding discussion two constants occur which are to be found by experiment, viz.:

$$\beta = \frac{p'}{f'\sqrt{V_{e2} + (2\pi n a r_1)^2}}$$

and

$$\varphi = \frac{n\,k\,r_1^2\,(V_e^2 + (2\pi n a r_1)^2)}{R}$$

We may obtain roughly approximate values for these by reference to examples of the common screw in practice.

The values to be found are

$$p_1 = \frac{R}{A} \text{ and } f' = \frac{V_1^2 - V_e^2}{2x_1}$$

The following data is obtained from the Report of a Board of U. S. Naval Engineers.*

The propeller used was a Department screw of the following dimensions:

Diameter, 5 ft.; pitch, 7·5 ft. at the boss, and 8·625 ft. at the periphery; fraction of pitch, $6\frac{5}{32}$ inches; helicoidal area, 7·3 sq. ft. The projected area, as measured by myself from the scale drawing† in the Report, was 5·2 sq. ft.

The following table gives mean results of trials on April 1st, 2d, and 3d, 1880.

Average Revolutions per minute.	Distance run by screw in knots.	Slip of Screw in per cent. of its speed.	Speed of ship in knots per hour.	Gross IHP high pressure cylinder.	Gross IHP low pressure cylinder.	Total Gross IHP.	Horse-power required to give a speed of ten knots.
153·39	14·708	15.493	11·015	64·0826	37·1259	101·2084	70·76

The resistance of the vessel is not given in the report, but we may probably find it by the formula

$$R = \frac{0{\cdot}6 \text{ IHP} \times 33000 \ddagger}{\text{pitch} \times \text{revs. per min.}}$$

By this we find $R = 1344{\cdot}7$ lbs.

From the Table we have $V_0 = 18{\cdot}57$ ft. per second, and $V_1 = 24{\cdot}85$ ft. per second, $x_1 = 0{\cdot}513$ and this is the same from root to tip.

Then we have $p' = \frac{R}{A} = \frac{1344.7}{5{\cdot}2} = 257{\cdot}6$ lbs. per sq. ft.

$$f' = \frac{V_1^2 - V_0^2}{2 x_1} = \frac{617{\cdot}5 - 344{\cdot}85}{1{\cdot}026} = 265{\cdot}7 \text{ ft. per sec.}$$

$$\beta = \frac{p'}{f' \sqrt{V_0^2 + (2 \pi n a r_1)^2}} = 0{\cdot}0274$$

which involves the assumption that $a = \frac{3}{4}$.

* Report of a Board of U. S. Naval Engineers of Experiments made on the Fish Commission Steamer "Lookout," November 24, 1880.

† See Plate II.

‡ This is based on Froude's experiments. See *Engineering*, vol. 21, p. 463.

Further, $$G = k\sqrt{V_0^2 + (2\pi n a r_1)^2} = 6{\cdot}28$$

hence $$k = \frac{6{\cdot}28}{\sqrt{V_0^2 + (2\pi n a r_1)^2}} = 0{\cdot}18$$

and $$\varphi = \frac{n k r_1^2 [V_0^2 + (2\pi n a r_1)^2]}{R} = 2{\cdot}7$$

The value of φ will be effected by the diameter of the boss, but as the part of the blade near the root does very little work, it will scarcely be worth taking into account.

RECAPITULATION.

In designing a wheel, when R is given, the following quantities are either determined by other considerations or assumed:

Revolutions per second, n.
Slip in feet per second, $V_1 - V_0 = G$.
Acceleration in feet per second, f.

When f and G vary with the velocity, $\sqrt{V_0^2 + v_0^2}$, the quantities to be assumed are m and k.

The intensity of thrust at the centre of effort is found by the formula

$$p' = f' M = f' \beta \sqrt{V_0^2 + (2\pi n a r_1)^2}$$

or for Case 4 when $f = m(V_0^2 + v_0^2)$

$$p' = m\beta [V_0^2 + (2\pi n a r_1)^2]^{\frac{1}{2}}$$

in which a is the ratio between the radius to the centre of effort and the radius to the periphery.

The radius of the wheel is to be found graphically, the projected area and all other quantities involved being known. The projected area is found by the formula

$$A = \frac{R}{p'}$$

The radius of the wheel in Case 4 may be found, when φ is known, by the formula

$$r_1 = \sqrt{\frac{V_0^2}{8(\pi n a)^2}\left\{\sqrt{1 + \varphi \frac{16 R n \pi^2 a^2}{V_0^4 k}} - 1\right\}}$$

All sections made by cylindrical surfaces having axes coinciding

with that of the wheel, are curves which, when developed, are represented by equation (2) as follows:

$$y = (H + h)(K - \tan.^{-1} X) + X(H + x)$$

in which $$H = \frac{V_0^2}{2f}; \; h = \frac{v_0^2}{2f};$$

$$K = \tan.^{-1} \frac{v_0}{V^0} - \frac{v_0 V_0}{V_0^2 + v_0^2}; \; X = \sqrt{\frac{h - x}{x - H}}$$

We have also the relation

$$2 f x_1 = V_1^2 - V_0^2$$

in which x_1 is the abscissa to the point in the trailing edge.

In Case 4, $f = m(V_0^2 + v_0^2)$; $G = V_1 - V_0 = k\sqrt{V_0^2 + v_0^2}$; $H + h = \frac{1}{2m}$; and $l_1 = \frac{k}{m}$.

EFFICIENCY.

I have considered loss of energy to be due to friction, slip, and edge resistance. In discussing the loss by slip this term will be used to indicate the total actual yield of the water, and not simply its longitudinal component. Only one case will be discussed, viz., Case 4, in which $f = m(V_0^2 + v_0^2)$ and $G = k\sqrt{V_0^2 + v_0^2}$.

The resistance by friction varies directly as the surface and as the square of the velocity. Therefore if K represent the resistance of a unit of surface at a unit velocity, the resistance for an elementary band, $l_1 d r$, will be

$$K l_1 d r (V_0^2 + v_0^2)$$

and the loss of work per second will be thus multiplied by the velocity $\sqrt{V_0^2 + v_0^2}$, which will give us, for both face and back of blade,

$$2 K l_1 d r (V_0^2 + v_0^2)^{\frac{3}{2}}$$

The integral of this between the limits r_1 and r_2 will give us the whole loss per second for one blade. Call this loss F. Then since l_1 is constant

$$F = 2 K l_1 \int_{r_2}^{r_1} \left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}} d r$$

$$= 2 K l_1 \left[\frac{r}{4}\left(V_0^2 + (2\pi n r)^2\right)^{\frac{3}{2}} + \frac{3}{8} V_0^2 \left(r\sqrt{V_0^2 + (2\pi n r)^2}\right.\right.$$

$$\left.\left. + \frac{V_0^2}{2\pi n} \text{hyp. log.} \left\{r + \sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\right\}\right)\right]_{r_2}^{r_1}$$

The resistance by friction of such a surface as a smooth propeller blade is 1¼ pounds per square foot at ten knots per hour, and it varies as the square of the speed nearly.* Whence we find that the resistance per square foot at the velocity of one foot per second is

$$K = 0{\cdot}00438 \text{ lbs.}$$

The loss of energy by slip will be proportional to the square of the velocity impressed upon the water during its contact with the blade. Consider the blade stationary and the water in motion so as to preserve the same relative conditions.

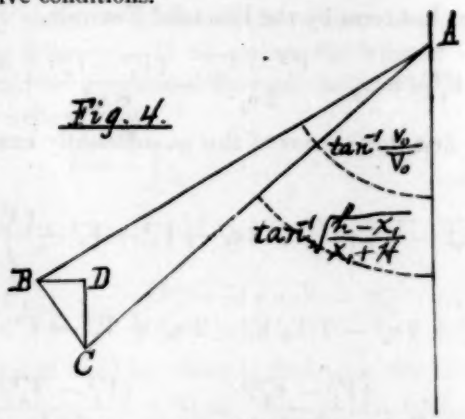


Fig. 4.

Let $A\,B$ represent the motion of the water, both in direction and velocity, at the leading edge; and let $A\,C$ represent its motion at the trailing edge. $A\,B$ and $A\,C$ are equal, for the velocity of the water relative to the blade is not changed by contact therewith; the *direction* of motion only is changed. $B\,C$, then, represents the change produced in the motion of the water, both in volocity and direction.

How the energy lost by slip is that which is *stored* in the yielding fluid. The general expression for it is $\frac{1}{2}\,M\,V^2$; from which it appears that the amount of lost energy is proportional to the square of the velocity impressed, that is, to $\overline{B\,C}^2$.

The mass acted upon is proportional to $\sqrt{V_0^2 + v_0^2}$. We may then write for the loss of energy by slip per second for an elementary band,

$$C\sqrt{V_0^2 + v_0^2}\,.\,\overline{B\,C}^2\,dr,$$

and for the whole blade, letting L represent the total loss,

$$L = C\int_{r_2}^{r_1} \overline{B\,C}\sqrt{V_0^2 + (2\,\pi\,n\,r)^2}\,.\,dr.$$

* Froude in Seaton's Manual of Marine Engineering, p. 288.

In this,

$$\overline{BC}^2 = \overline{AB}^2 + \overline{AC}^2 - 2\,\overline{AB}\,.\,\overline{AC}\,.\cos.\,BAC.$$

$$= 2(V_0^2 + v_0^2)\left\{1 - \cos.\left[\tan.^{-1}\frac{v_0}{V_0} - \tan^{-1}\sqrt{\frac{h - x_1}{x_1 + H}}\right]\right\}$$

$$= 2(V_0^2 + v_0^2) - 2V_0\sqrt{V_0^2 + 2fx_1} - 2v_0\sqrt{v_0^2 - 2fx_1}$$

$$= 2(V_0^2 + v_0^2) - 2V_0V_1 - 2v_0\sqrt{v_0^2 - V_1^2 + V_0^2}$$

Developing the last term by the Binomial Formula,

$$(v_0^2 - (V_1^2 - V_0^2))^{\frac{1}{2}} = v_0 - \frac{V_1^2 - V_0^2}{2v_0} - \frac{(V_1^2 - V_0^2)}{8v_0^3} - \frac{3(V_1^2 - V_0^2)^3}{48v_0^5}, \text{ etc.}$$

Taking the first three terms of this as sufficiently exact for our purpose, we have

$$2v_0\sqrt{v_0^2 - V_1^2 + V_0^2} = 2v_0^2 - V_1^2 + V_0^2 - \frac{(V_1^2 - V_0^2)^2}{4v_0^2}$$

whence

$$\overline{BC}^2 = 2V_0^2 + 2v_0^2 - 2V_0V_1 - 2v_0^2 + V_1^2 - V^2 + \frac{(V_1^2 - V_0^2)^2}{4v_0^2}$$

$$= (V_1 - V_0)^2 + \frac{(V_1^2 - V_0^2)^2}{4v_0^2} = G^2 + \frac{(V_1^2 - V_0^2)^2}{4v_0^2}. \qquad (4)$$

But $$V_1 = G + V_0 = k\sqrt{V_0^2 + v_0^2} + V_0$$

$$\therefore \quad \overline{BC}^2 = k^2(V_0^2 + v_0^2) + \frac{[k^2(V_0^2 + v_0^2) + 2kV_0\sqrt{V_0^2 + v_0^2}]^2}{4v_0^2}$$

which, expanded, becomes

$$\overline{BC}^2 = k^2v_0^2 + 2k^2V_0^2 + \frac{k^4V_0^4}{4v_0^2} + \frac{k^4V_0^2}{2} + \frac{k^4v_0^2}{4} + \frac{V_0k^3(V_0^2 + v_0^2)^{\frac{1}{2}}}{v_0^2} + \frac{k^2V_0^4}{v_0^2}$$

Substituting this value of $\overline{BC}^2$ in our original equation, and arranging terms, we have

$$L = ek^2\int_{r_2}^{r_1} dr\,(V_0^2 + v_0^2)^{\frac{1}{2}}\left[v_0^2(1 + \tfrac{1}{4}k^2) + \frac{V_0^4}{v_0^2}(1 + \tfrac{1}{4}k^2) + \frac{V_0k(V_0^2 + v_0^2)^{\frac{1}{2}}}{v_0^2} + V_0^2(2 + \tfrac{1}{2}k^2)\right].$$

Integrating, we have for the loss of energy by slip per second for one blade,

$$L = c\,k^2\left[\frac{1+\frac{1}{4}k^2}{4}\left(r-\frac{V_0^2}{\pi^2 n^2 r}\right)\left(V_0^2+(2\pi n r)^2\right)^{\frac{1}{2}} + \right.$$

$$\left.\frac{15}{8}\,r\,V_0^2\,(1+\tfrac{1}{4}k^2)\left(V_0^2+(2\pi n r)^2\right)^{\frac{1}{2}} + \frac{15}{8}\,\frac{V_0^4(1+\frac{1}{4}k^2)}{2\pi n}\text{hyp.log.}\right.$$

$$\left.\left(r+\sqrt{\frac{V_0^2}{4\pi^2 n^2}+r^2}\right)+V_0 k\left(2\,V_0 r+\tfrac{4}{3}\pi^2 n^2 r^3-\frac{V_0^4}{4\pi^2 n^2 r}\right)\right]_{r_2}^{r_1}$$

The edgeway resistance of the blade varies as the square of its velocity and as its thickness. If we assume the latter to vary inversely as the radius, and let T represent the total loss per second due to this cause, we may write at once

$$T = d\int_{r_2}^{r_1}\frac{(V_0^2+v_0^2)^{\frac{1}{2}}\,dr}{r}$$

$$= d\left[\tfrac{1}{3}\left(V_0^2+(2\pi n r)^2\right)^{\frac{1}{2}} + V_0^2\left\{\sqrt{V_0^2+(2\pi n r)^2}+\right.\right.$$

$$\left.\left.V_0\,\text{hyp. log.}\,\sqrt{\frac{V_0^2+(2\pi n r)^2}{2\pi n r}}-V_0\right\}\right]_{r_2}^{r_1}$$

I have no data at hand by which to determine the value of the constants c and d.

Calling the efficiency E, and the energy transmitted to the wheel per second, W, we have

$$E = \frac{W-\Sigma\text{ losses}}{W}$$

$$= 1-\frac{N}{W}[F+L+T] \qquad (5)$$

N being the number of blades.

These expressions for the losses apply only to the case assumed, viz.: that in which

$$f = m\,(V_o^2+v_o^2)\text{ and }G = k\sqrt{V_o^2+v_o^2}$$

In a propeller wheel, that part of the blade which is nearer the hub is inefficient on account of lateral slip, while that part which is near the periphery is inefficient on account of friction, I have therefore assumed G, the longitudinal slip, to diminish from the periphery to the hub, in order to lessen the amount of work done at an inefficient part of the blade; and have taken f as increasing from hub to periphery in order to avoid too great a width at the latter. The edges should be

sharpened from both face and back, and it would be advisable to round the corners as is done in ordinary practice.

I will now consider briefly, the

PROPELLER WITH GUIDE BLADES.

The primary object of guide blades is to prevent loss by lateral slip. They give an additional advantage, however, by increasing the efficiency of the central part of the wheel, so that for a given thrust, a smaller diameter may be used than with the common wheel.

The guide blades should be placed behind the propeller. It would, perhaps, be better to place them in front of the wheel, if we considered only the action while going ahead; but when going astern this arrangement would be very ineffective.

In applying the method of the previous discussion we have but to take G constant and $f = m\sqrt{V_0^2 + v_0^2}$. The guide blade should be constructed in the same way as the propeller blade, using for V_0 the lateral slip, found thus:

By equation (4) we have

$$\overline{BC}^2 = G^2 + \frac{(V_1^2 - V_0^2)^2}{4\,v_0^2}$$

This last term must represent the lateral slip $B\,D$, figure 4; hence,

$$BD = \frac{V_1^2 - V_0^2}{2\,v_0}$$

In case the guide blades are placed before the wheel, the initial whirling velocity, v_0, of the water relative to the wheel, would no longer be the velocity of the latter, but would be this velocity plus the velocity imparted by the guide blade. That is

$$v_0 = 2\pi n r + BD = 2\pi n r + \frac{V_1^2 - V_0^2}{2\,v_0}$$

whence

$$V_0 = \pi n r + \sqrt{\pi^2 n^2 r^2 + \tfrac{1}{2}(V_1^2 - V_0^2)}$$

A comparison between the efficiencies of the guide blade propeller and the common wheel reduces itself to a comparison between the lateral slip of the common wheel and the excess of friction of the guide blade wheel over the common one. The frictional loss is found in both cases by the formula for F, which applies to any blade of constant width. If the guide blade wheel is enclosed in a cylinder, the friction of this also is to be taken into account.

For the lateral slip we have:

Loss of energy per second by lateral slip for one blade

$$D = C \int_{r_2}^{r_1} \overline{DB}^2 \sqrt{V_0^2 + V_\circ^2}.\, dr$$

$$= \frac{C}{4} \int_{r_2}^{r_1} \frac{(V_1^2 - v_0^2)^2}{V_\circ^2} \sqrt{V_\circ^2 + v_\circ^2}.\, dr$$

$$D = \frac{c\,k^2}{4}\Big[\tfrac{1}{4}\left(k^2 r - \frac{V_\circ^2(k^2+4)}{\pi^2 n^2 r}\right)\left(V_\circ^2 + (2\pi n r)^2\right)^{\frac{3}{2}} +$$

$$V_\circ^2 r\,(2k^2+6)\left(V_\circ^2 + (2Vnr)^2\right)^{\frac{1}{2}} + \left(\frac{15}{8}k^2+6\right)\text{hyp. log.}\,(r+$$

$$\sqrt{\frac{V_0^2}{4\pi^2 n^2} + r^2}\,\Big) + 4\,k\,V_\circ\left(2\,V_0^2 r + \tfrac{4}{3}\pi^2 n^2 r^3 - \frac{V_0^4}{4\pi^2 n^2 r}\right)\Big]_{r_2}^{r_1}$$

which applies to a wheel having the conditions of case 4. This expression involves also the loss by centrifugal action, which in the guide blade wheel can be counteracted by a proper adjustment of the guides.

If F_1 and F_2 represent the fractional losses of the common and and guide-blade wheel respectively, then a comparison between D and $(F_2 - F_1)$ will determine the relative efficiency.

Fig. 5 Fig. 6.

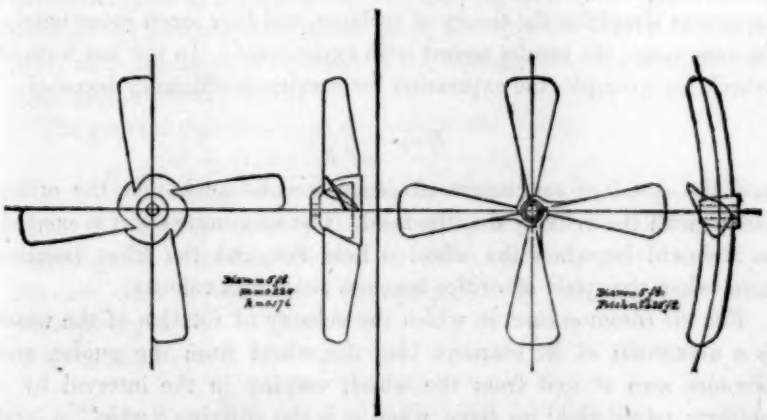


Fig. 5 shows a wheel designed by the method of Part II with the conditions of Case 4. It is calculated to exert the same thrust as the wheel shown in Fig. 6, which is a U. S. Navy Department wheel.

Hoboken, N. J., June, 1883.

NOTE ON CENTRIFUGAL FORCE IN TURBINES.

By R. H. THURSTON.

[American Association for Advancement of Science, August, 1883.]

A note by Mr. J. P. Frizell (JOURNAL OF THE FRANKLIN INSTITUTE for June) especially interests the writer, as he has, recently, also noted the same defect in the accepted theory. It is so obvious as to require no proof that centrifugal force, even where it is necessarily considered at all, depends for its measure upon the actual rotation of the mass of fluid, and not at all upon the movement of the wheel, except so far as the latter controls the former. In water-wheels, the two rotations are very different in their angular measures.

Plotting the path of the water in space, it will often be found that the line is so nearly rectilinear that the action of this force may be neglected as unimportant in practice. This is probably the case, for example, in the Vallet wheels. In the Whitelaw turbine, or "Scotch reaction wheel," as it is sometimes called, the spiral form given the arms may often be given such proportions that the path of the water may be nearly a straight line to the exit, and centrifugal force thus rendered so small that it may be neglected in the theory of that wheel. The writer has been interested in noting how much this method of treatment simplifies the theory of turbines, and how much more nearly, in some cases, the results accord with experiment. In the last form of wheel, for example, the expression for maximum efficiency becomes

$$E = \frac{1}{sec^2\,\theta},$$

and the speed of maximum efficiency becomes such that the orifice moves with the velocity due the head. The maximum effort is exerted, as it should be, when the wheel is held fast, and the effort becomes zero, when the speed of orifice becomes twice that velocity.

For the common case, in which the velocity of rotation of the water is a maximum at its entrance into the wheel from the guides, and becomes zero at exit from the wheel, varying in the interval by a uniform retardation, we have, when v_1 is the entering "*whirl*," r_1 and r_2 are the two radii of the wheel, and $r_2 = n\,r_1$;

$$v = \frac{r_2 - r}{r_2 - r_1}\,v_1 = \frac{n - \frac{r}{r_2}}{n - 1}\,v_1;$$

the work done by or against centrifugal force is

$$W = \frac{D\,Q}{g}\int_{r_1}^{n\,r_1}\frac{v^2}{r}\,dr;$$

$$= \frac{D\,Q}{g}\cdot\frac{v_1^{\,2}}{(n-1)^2}\int_{r_1}^{n\,r_1}\left(n-\frac{r}{r_2}\right)^2\frac{dr}{r};$$

$$= D\,Q\,\frac{v_1^{\,2}}{2g}\cdot\frac{2\,n^2\,log_{\epsilon}\,n - 4\,n\,(n-1) + n^2 - 1}{(n-1)^2}$$

Applying this to the outward flow wheel of the Fourneyron type, having uniform radial flow, it is found that the effort due centrifugal force is about one-quarter the head due the velocity of entering whirl; but this velocity is that due to about one-third the total head, in this particular example, and it follows that the accelerated flow is not far from one-half that predicted by the usual theory, and is not very far from what Mr. Frizell gives as the results of Mr. Francis' experiments, and if the energy is given a uniform decrement, *i. e.*, $dv^2 =$ constant and $dv \propto \frac{1}{2v}$, for which case, $f(n) = \frac{2n\,log_{\epsilon}\,n - 2(n-1}{n-1}$, the correspondence is almost exact, a coincidence, possibly, however, as the writer has not investigated that particular case.

It thus becomes evident that, in the general equation of efficiency for wheels of uniform radial flow, for which the writer gets the expression below, the functions representing this force may take the place in the formula there given them, and that the theory of the turbine, thus modified, is a much more manageable one in application than that previously held.

The general equation is, as derived by the writer,

$$E = \frac{(n^2+1)\,(2\,a\,r_1\,v_1 - a^2\,r_1^{\,2}) - f(n)\,v_1^{\,2}}{n^2\,v^2\,sec^2\,\theta + 2\,a\,r_1\,v_1 - a^2\,r_1^{\,2} - f(n)\,v_1^{\,2} + f(f)v_1^{\,2}}$$

when the angular velocity is denoted by a and the coefficients for centrifugal force and for friction are taken constant, as they may be for any one class of wheel, as $f(n)$ and $f(f)$, the delivery angle of the wheel being θ.

At the best speed, $v_1 = a\,r_1$; and

$$E = \frac{(n^2+1) - f(n)}{n^2\,sec^2\,\theta + 1 - f(n) + f(f)};$$

which becomes unity when $f(f) = 0$ and $\theta = 1$. It is seen that the value $f(n)$ appearing in both numerator and denominator affects efficiency but little, since the expression is, for good wheels, nearly unity.

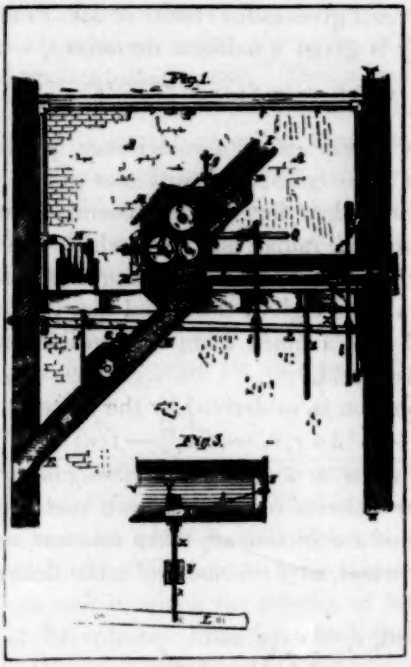
Hoboken, July 31, 1883.

PREVENTION OF DUST EXPLOSIONS AND FIRES IN MALT MILLS.

By C. JOHN HEXAMER.

[Read at the Stated Meeting of the Franklin Institute, June 20, 1883.]

In consequence of the lateness of the hour at which I spoke, and not having satisfactory drawings prepared at the time, I did not explain my automatic devices (for closing communicating openings between the mill house and the brewery, and for turning on live steam and a supply of water automatically by an explosion or fire) in my paper on "Dust Explosions in Breweries," read before the Institute, January 17th, 1883, and published in the JOURNAL for February.



Without taking your valuable time for a recapitulation of what I then said concerning the hazards of malt mills, I will ask your kind attention to Fig. 1, which represents a vertical section of the mill room; the heavily shaded sections on the extreme right and left represent the walls of the mill building; *I* the influx pipe of the grain as it comes

from the cleaners; *M* the mill box, containing a feeding device *g* and *c*; *R R* the crushing rolls; *f* a live steam supply pipe with openings *o*, *o*, *o*, *o*, into the mill box; *E* the exit or grain discharge pipe; *G*, *C* the discharging apparatus, above which is shown a plenum of ground malt; *J* a gate attached to the lever *L* by the rod *r'*; *V* a large vent pipe, extending from the mill box through the wall to the outside of the building, closed by the capping *Z*; *T* a water pipe with sprinkler openings *t*, *t*; *H* a hose attached to the water pipe.

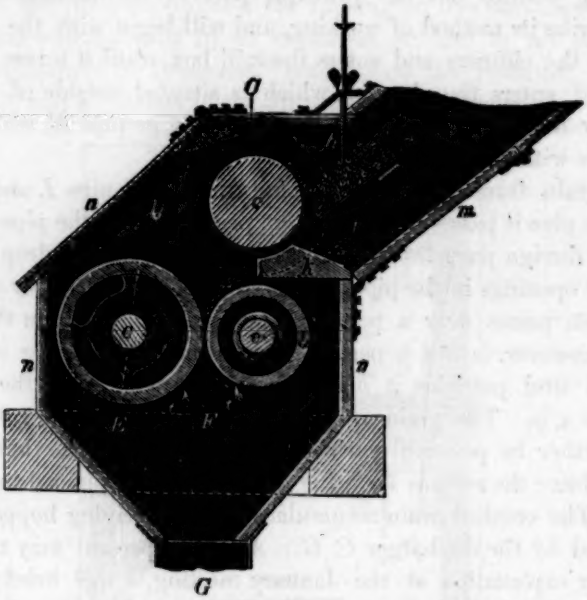
Having pointed out the principle parts of the mechanism, I will now describe its method of working, and will begin with the grain as it leaves the cleaners and enters the mill box, until it leaves the mill room and enters the elevator, which is situated outside of the mill room beyond the wall to the left and discharge pipe *E*, which communicates with it.

The grain from the cleaners enters the influx pipe *I*, and rolling down the pipe it passes over sieve-like perforations in the pipe, causing dust and foreign particles smaller than the malt grains to drop through the small openings in the pipe into an inclosed dust chamber *m*. The grain then passes over a powerful magnet, not shown in the figure (which, however, is not a part of my invention), cleaning it of the iron and steel particles it may contain. It now enters the feeding apparatus *c*, *g*. The grain is then fed into the *gearing* rolls *R*, *R*, held together by powerful springs shown on the outside (left side) of the mill box; the reasons for using these I fully explained in my last paper. The crushed grain accumulates in the receiving hopper and is discharged by the discharger *C*, *G*. As many present may not have heard my explanation at the January meeting, I will briefly repeat the reasons for the introduction of the feeding and discharging device which otherwise might to many seem but an unnecessary complication.

The great danger in malt mills is that, in case of an explosion, the explosive force and fire are not confined to the mill only, but run from the mill into the elevator, and from there are distributed to the adjoining brewery buildings. To check the force and fire of an explosion we must put a barrier between the mill box and the elevator. This can best be accomplished by placing a receiving hopper below the rolls, kept well filled while the mill is in operation, and from this hopper feed into the elevator cups. We thereby have a barrier of meal between the elevator and the mill, a barrier almost as effective as one of sand. But the important point in this case will be to keep the hopper

well filled, for a hopper which is not full merely acts as a conduit and not as a barrier to an explosion. In order that the attendant of a mill shall not be relied upon, the receiving hopper should be kept filled automatically. For this purpose I suggested the following device, shown in the accompanying cut (Fig. 2); a device which was not a new invention, but an adaptation of something well known, for a new purpose. A "feeder" for grain mills used for a long time in Germany is

Fig. 2.



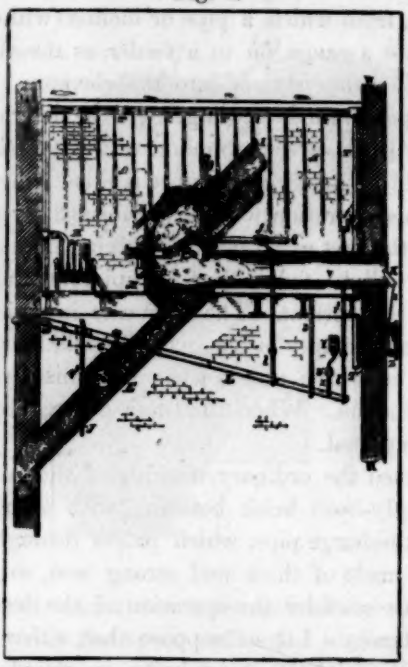
shown in the cut, e and e^1 being the rolls of the mill, n, n, being the mill box, while G is the spout ordinarily leading into the elevator boot; in mills properly constructed, into a receiving hopper; c is a roll of wood usually covered with a covering, and teeth d of steel projecting from 2 to 3 millimeters, we propose to use a covering and teeth of copper, phosphor bronze, or some other metal which will strike no sparks; l is an inclined plane of metal with sieve-like perforations large enough to allow dust to drop through them; h is a gauge which regulates the flow of grain on to the feeding roll c; l^1 is a "dust chamber," which may be made of any size, and which may be cleaned out through the door m; k is the receiving block of wood covered

with copper, and at a distance of 1·9 millimeters from the teeth of the feeding roll. The operation of this feeder, which is a Belgian invention, and which has been used with great success in Germany, is very simple. The grain after passing through a cleaner drops on to the incline, is there separated from any remaining dust; and is then allowed to run in a thin stream—regulated by the gauge—on to the receiving block, where it is fed into the mill by the revolution of the feeding roll. We propose to utilize this invention, modified as above, to keep our receiving hopper at all times full. The crushed grain instead of falling directly into the elevator cups on leaving *G*, will fall into a receiving hopper, from which a pipe or incline (without perforations) leads the meal past a gauge, on to a feeder as described above, from which it passes in a thin stream into the elevator. On setting up a mill the relative points for both gauges will be determined, the grain-feeder and the mill will be set in motion while the *discharger* will remain at rest until the receiving hopper is filled, when it will also be set in motion; this operation will be performed by the erecting machinist; for after the first grinding the receiving hopper will always be full, as the grain will be fed in just as rapidly at the top as the meal is discharged at the bottom. The only case in which the receiving hopper could become empty is one, which would very rarely occur in a well-conducted brewery; that is when the mill is running while no grain is on the incline. When this does occur, the above-described process must be repeated.

Having explained the ordinary working of the mill, which is contained in a strongly-built brick building, with a brick arched floor and ceiling, the discharge pipe, which passes through the brick and iron floor, being made of thick and strong iron, so as to withstand great shocks, let us consider the operation of the device under extraordinary circumstances. Let us suppose that, either by the striking of a spark or frictional heat, an explosion is caused in the mill box (explosions and fires almost invariably originate in the mill box at the rolls). The tendency of all explosions or pent-up forces is to seek the easiest means of exit, and would in this case, in all probability, pass out through the large-sized vent pipe *V* (Fig. 1), knocking out the capping, *Z*. Fig. 3 shows an enlarged section of the vent pipe and arrangement of the capping. The cap *Z* consists of a hood similar, only larger in size, to the caps used in summer to close up stovepipe holes. To this cap is attached a rod *Q*, which connects the caps with

a key x, fitting into the slotted support y, which passes through an opening in the bottom of the ventpipe. The key and its slotted holder will be made either of a certain variety of vulcanized rubber, with which I am at present experimenting, or of boxwood soaked for a time in oil. The cap being knocked off, the rod Q would dislodge the key x; the support y would pass through the slit in the vent pipe, and the lever L, supported by the rope Xx, would be released and drop. The lever, which is weighted at the point of contact with the rope x, has its fulcrum at w (Fig. 1), where it is attached to the

Fig. 4.



wall. In falling, the lever carries with it the rod r'', which is connected as shown in Fig. 1 with the cock f' of the water supply pipe T, and by falling turns on the water, which rushes into the sprinklers t, t and hose H. The lever L also carries with it the rod r', connected with the cock f of the life steam supply pipe, turning on the steam, which rushes into the mill box through the numerous openings o, o, o. At the same time a strong rod r', attached to an iron gate J, is forced down, cutting off all communication between the mill room and the elevator in the adjacent brewery. This gate, on falling, will meet

with no serious obstacles from crushed grain in the pipe at this point, as the grain is only discharged in a thin, regular stream by the discharger *G C*.

The result of all this is shown in Fig. 4. The steam is rushing into the mill box; the water is turned on; the hose and sprinklers are in operation; the gate is shut, etc.

An explosion would not likely find an exit in the supply pipe *I*, as this is securely closed by the wheel *c*, the strong gauge, *h* and a plenum of malt *l* (Fig. 4), while the effect of an explosion on the exit pipe *E* (Fig. 1) would be to pack the crushed malt more tightly, forming a more impenetrable barrier than before, as is the case in the well-known experiment of "a funnel filled with sand."

But let us suppose that the mechanism does not work as we anticipated. Let us suppose that the capping is rusted fast; that the key sticks, or, as has just been suggested by one of the members, that the explosion does not follow out the easy path I have made for it, but knocks the strongly-built mill box to pieces, what will occur? In this case the fire will not be as readily smothered as would have been the case under the first supposition, when it would have been "nipped in the bud." But the heat in the mill room would soon rise to a considerable temperature, and on reaching 150° Fahrenheit, would melt the fusible solder catches which join the different sections of the rope,* *x*, *x* (Fig. 3), *v* being one of them greatly exaggerated; the lever *L* would fall, and the mechanism would work as well as in the first case described. Let us make the very improbable supposition that the fusible catches, by some unforseen accident, will not operate. In that case the flames, which spread very rapidly throughout the finely-divided dust in the room, would soon reach the portion of the rope *x*, *x*, above the floor. This, which is prepared especially inflammable, would rapidly burn through, and the mechanism operate as before.

So that the building may not be flooded and filled with steam after the fire is extinguished, there are cocks (not shown on the figure) on the supply pipes, placed below the automatic cocks, by which the water and steam may be turned off until the apparatus is repaired. That no ignorant or malevolent employé may turn these off, and thus throw out the supply of the automatic system, the lower cocks are so arranged that they cannot be turned unless the lever *L* has fallen.

* The rope consists of small, extremely inflammable prepared sections, held together by fusible catches.

Instead of steam, a supply of carbonic acid gas might be turned on automatically in the same manner; but as it would be more costly and troublesome to keep a supply of this on hand, it is preferable to use steam, especially as there must always be a supply of steam in the boiler, while there is danger of an explosion or fire—that is, while the mill is running.

In reply to a question of one of the members, I will also state that the iron gate *J* has only been introduced as another factor of safety, for as long as the mill is properly operated—that is, as long as the receiving hopper is kept full, the crushed grain will form a perfect barrier to all explosions. It is only where the mill has been carelessly allowed to run without feeding and grinding, and the hopper has thus become empty, and not being refilled at the next grinding, an occurring fire would, by the automatically closing gate, be prevented from entering the adjoining brewery building through the exit pipe E (Fig. 1).

THE GREEN MOUNTAIN RAILWAY.*

The leading attraction which Maine has to offer her summer visitor the present season is her mountain railway—from the shore of Eagle Lake to the summit of Green Mountain, on the Island of Mount Desert.

Several weeks since, we promised our readers a more detailed description of this railway and its leading features of construction than had been given to the public, as the fact of its being the second cog railway in this country and the third ever in existence has made the work one of more than ordinary interest.

The survey for the Green Mountain Railway was made in December and January, 1882–3, by Mr. Alden F. Hilton, formerly Engineer of the European & North American Railway. The mountain at the time was covered with snow and ice, and during the entire progress of the survey the mercury indicated nothing above a zero temperature, and was some of the time eight degrees below. The point first selected turned out to be the very best location on the whole mountain and was followed in the construction of the line, as was also the whole general plan proposed by Mr. Hilton. He was called away, however, on the

* Abstracted from the *Mining and Industrial Journal*, Bangor.

Megantic survey, and Mr. Warren Nickerson, of Orrington, was employed as constructing engineer, under whose supervision the entire work of construction was performed.

THE ROADWAY.

The roadway for the most part, and over all heavy grades, is constructed upon the solid ledge. Where the stringers (longitudinal timbers) rest directly on the ledge, an iron bolt (1¼ inch iron) is driven through the timbers and into the ledge at intervals of six feet. Where, in order to make regular grades, the stringers are raised above the surface, bed ties are used every six feet, and back of every bed tie, on all ledges, two and three 1¼ inch iron bolts are firmly set into the ledge. Not only this, but all longitudinal timbers upon the bed ties are bolted to them with the 1¼ inch bolts, and every stick resting upon the ledge is carefully fitted to its inequalities, some sixty first-class ship-carpenters and axemen having been employed upon the work expressly for this purpose, at prices ranging from fifty to seventy-five per cent. above the cost of labor in ordinary railroad construction. The stringers were all laid true to grade, and the "centres" given from the instruments on every bed tie.

The track ties (sleepers) are laid directly upon the stringers, exactly two feet apart (from centre to centre), and back of each tie (which is six inches square by six feet long) two ⅞ inch iron bolts are driven into the stringers, each tie being grooved or "gouged" so that the bolts fit firmly into them, thus preventing lateral as well as longitudinal movement.

THE TRACK.

Upon these ties the "T" (or ordinary track) rails are laid to a gauge of 4 feet 7½ inches, or one inch narrower than the standard gauge railways of the country. These rails are coupled together the entire length of the road by the ordinary "fish plates" and track bolts (four bolts to each rail), and fastened to the sleepers by common railroad spikes, two upon each end of every sleeper. Every T rail has also four "slots" into which the spikes are firmly fitted. The cog rail is made from two plates of angle iron which form the base as well as the upright stand into which the cogs are fitted. The "cogs" are made from 1¼ inch iron, especially selected for the purpose, and all made in one set of rolls in order to insure uniformity in size. Each bolt is

equal to a *direct* strain of about thirty tons, while the maximum load will never exceed sixteen tons. These cog rails are secured to the ties by fourteen lag screws (5½ inches long) in each 12-foot section of the rail, or two lag screws every two feet, this of course being doubled at each joint.

For the purpose intended, the road is without doubt equal to five times the strain to which it will ever be subjected, and, considering the difficulties under which it was built, is certainly a marvel of railway engineering and construction.

THE ROLLING STOCK.

The engine was built by the Manchester Locomotive Works, with all the improvements suggested by thirteen years' successful operation of the White Mountain road. The ascent is made by steam power; the descent with compressed air—or perhaps it is more correct to say through allowing the air to escape from the cylinders. The engine is always set in the "forward gear"—or as if going ahead—even in coming down the mountain, and is never reversed when backing up as is the case with an ordinary locomotive. As an illustration, let us suppose a "dead" engine—or an ordinary locomotive with no steam—standing on a level track and set in the forward gear. Attach an engine under steam and haul the dead locomotive backwards a considerable distance. Release it, and the compressed air worked into the cylinders and boiler will send it forward to the starting point. The action is precisely the same with the mountain engine, and it absolutely cannot come down the mountain excepting as the air is allowed to escape.

The entire mechanism of the engine is double—four cylinders, two cog wheels and two driving shafts. The power is not carried direct from the cylinders to the cog wheel axle, but to shafts upon which there is a small gear wheel which works into one 5½ times its size upon the cog wheel axle. Upon the cog wheel axles there are two ratchet wheels into which two pawls are constantly dropping, and in the event of the breaking of any part of the engine, either one of these wheels, with its pawl, will hold the entire train on any of the grades. In addition to these provisions for safety, there are two "band" brakes on the smaller shafts which may be instantly applied by the engineer.

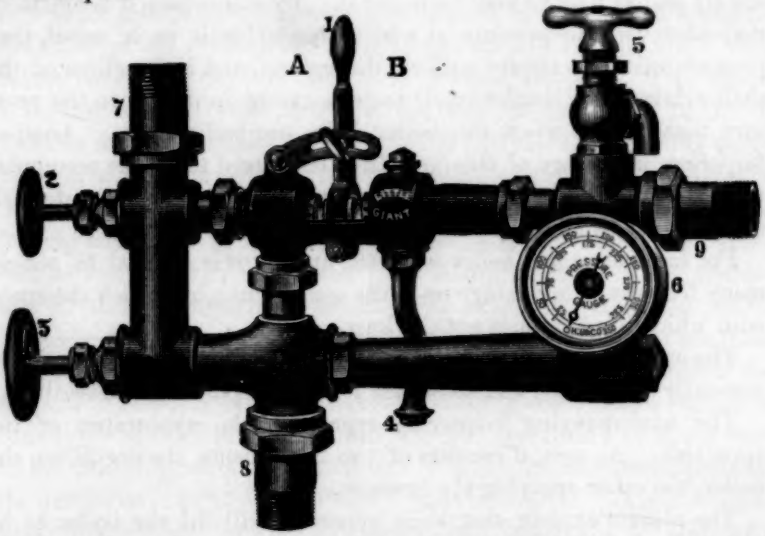
The passenger and construction cars were built by the Hinckley &

Egery Iron Company, of this city, the former being transported in sections to the foot of the railway and there set up. The floor and seats are adjusted to the average grade, and the sides are open to admit of unobstructed observation, and the construction is first class in every respect. The car is never attached to the engine, but is pushed ahead. It is provided with double hand-brakes, two cog wheels, and a rachet wheel with a pawl, which would instantaneously stop and hold the car on any of the steepest grades, if it were ever possible for the engine to get away.

IMPROVEMENTS IN APPARATUS FOR TESTING BOILERS.

[From the Report of the Secretary, May 16, 1883.]

The accompanying illustration represents the "Little Giant" Boiler Testing Apparatus, made by the Rue Manufacturing Company of Philadelphia.



Respecting the usual cold water test applied for this purpose, it is alleged that the shock of forcing water into a boiler under pressure by means of a pump is equivalent in its effects to a series of blows against the boiler shell; and that these blows are liable to, and in many instances do, result in producing serious injury to the boiler, the extent of which in the majority of instances may never be known save indi-

rectly. If strained by this operation in some of its parts, to nearly the point of rupture, it is reasonably alleged that it may give way at some future time under a much less pressure than that at which it was tested.

From these considerations, therefore, it is affirmed that the safest method of making such tests and that which has received the sanction of experienced engineers, has hitherto been to fill the boiler full of cold water, then apply a slow fire and obtain the desired pressure by the expansion of the water.

The method which involves the application of the apparatus herewith illustrated, consists in filling the boiler full of hot water (of say 180°F. or more), then applying the required pressure by means of an injector constructed for the purpose, which also continues to add heated water to the boiler. A safety- or relief-valve is set to open at the pressure at which it is desired to test the boiler, and the operation of the injector is such as to accumulate and maintain that pressure constantly and as long as may be required. By this means, it is affirmed, that whatever the pressure at which the boiler is to be tested, that pressure will be perfectly uniform throughout, and in its effects on the shell substantially similar in all respects except in degree to the pressure that obtains when the boiler is in use under steam. Another important advantage of this apparatus is claimed to be the accumulation and constant maintenance of whatever pressure may be desired, uninfluenced by slight leaks.

For locomotive and boiler work the apparatus is claimed to possess many features of advantage over the usual pump, of which the speed with which it operates, is not the least.

The apparatus consists in the arrangement of an injector and ejector especially constructed and connected for the purpose above described.

The accompanying engraving represents the appearance of the apparatus. As seen, it consists of two instruments, the one filling the boiler, the other applying the pressure.

The makers explain that their apparatus will fill the boiler to be tested at the rate of 2,000 gallons per hour with hot water. The portion of the apparatus applying the pressure has a capacity of 400 gallons per hour, and will accumulate from three to five times the initial pressure according to circumstances. It is further explained that it can be used with any pressure of steam from 10 pounds to 150 pounds.

Briefly, then, the instrument herewith shown is an apparatus to test boilers with warm water under a continuous even pressure without shock or jar, which cannot be done with a pump and cold water; it will produce and maintain any desired pressure up to three times the steam pressure used, and can be made to five times when required.

The details of the apparatus will be understood from the following references to the engraving:

No. 1. Adjusting Lever, Instrument, No. 1.
No. 2. Steam Valve, Instrument, No. 1.
No. 3. Steam Valve, Instrument, No. 2.
No. 4. Overflow from Instrument, No 1.
No. 5. Safety Valve.
No. 6. Pressure Gauge.
No. 7. Steam Connection.
No. 8. Water Connection.
No. 9. Boiler Connection.

MINERAL PRODUCTS OF THE UNITED STATES.

A report entitled "The Mineral Resources of the United States" is now in the press, and will shortly be published, by Mr. Albert Williams, Jr., chief of the division of Mining Statistics and Technology, United States Geological Survey, Hon. J. W. Powell. Director. This report is for the calendar year 1882 and the first six months of 1883. It contains detailed statistics for these periods and also for preceding years, together with much technical and descriptive matter. The compilation of special statistics has been placed by Mr. Williams in the charge of leading authorities in the several branches, and the results will therefore be accepted with confidence. The following totals of the production of the more important mineral substance are from advanced proofs:

Coal.—The only statistics in which the trade is interested are those relating to the amount of coal which is mined for and reaches the market. There is besides a local and colliery consumption which is usually disregarded in statistics, and which ranges from 5 to 6½ per cent. on the total shipments. Of what may be called the commercial product, the quantities in 1882 were: Pennsylvania anthracite, 29,120,096 gross tons; bituminous, brown coal, lignite, and small lots of anthracite mined outside of Pennsylvania, 57,963,038 gross tons; total, 87,083,-134 gross tons. The spot value of the commercial product was as follows: anthracite, $65,520,216; bituminous and other coals, $72,-453,797; total, $137,974,013. During the first six months of 1883 the output was: Pennsylvania anthracite, 14,010,767 gross tons; bituminous and all other coals, 30,000,000 gross tons; total, 44,010,767

gross tons. The spot value of the commercial product during the first half of 1883 was: Pennsylvania anthracite, $31,524,226; bituminous and other coals, $37,500,000; total, $69,024,226. Including the local consumption, etc., the total product in 1882 may be stated at 92,219,454 gross tons; namely, 31,358,264 tons of Pennsylvania anthracite and 60,861,190 gross tons of other coals; and the value at the mines was: Pennsylvania anthracite, $70,556,094; bituminous coal, etc., $76,076,487; total, $146,632,581.

Iron.—The principle iron statistics for 1882 are as follows: Pig iron made, 4,623,323 gross tons; spot value, $106,336,429. Iron ore mined, 9,000,000 gross tons; spot value, $32,400,000. Domestic iron ore consumed, 8,700,000 gross tons; spot value, $31,320,000. Imported iron ore consumed, 589,655 gross tons. Total iron ore consumed, 9,289,665 gross tons. Total spot value of all iron and steel in the first stage of manufacture, excluding all duplication, $171,336,429. Anthracite consumed in all iron and steel works, including furnaces, 3,800,000 gross tons. Bituminous coal consumed in all iron and steel works, including furnaces, 6,600,000 gross tons. Coke consumed in all iron and steel works, including furnaces,3,350,000 gross tons. Charcoal consumed in all iron and steel works, including furhaces, 107,000,000 bushels. Limestone consumed as flux, 3,850,000 gross tons; spot value, $2,310,000.

For the first six months of 1883 the totals are as follows: Pig iron made, 3,352,019 gross tons; spot value, $47,040,380. Iron ore mined (and consumed), 4,500,000 gross tons; spot value, $12,375,000. Imported iron ore consumed, 185,000 gross tons. Total iron ore consumed, 4,685,000 gross tons. Total spot value of all iron and steel in the first stage of manufacture, excluding all duplications, $71,000,000. Anthracite consumed in all iron and steel works, including furnaces, 1,810,000 gross tons. Bituminous coal consumed in all iron and steel works, including furnaces, 3,140,000 gross tons. Coke consumed in all iron and steel works, including furnaces, 1,780,000 gross tons. Charcoal consumed in all iron and steel works, including furnaces, 38,750,000 bushels. Limestone consumed as flux 1,950,000 gross ton; spot value, $1,072,500.

Gold and silver.—The Mint authorities furnish the following statistics for 1882: Gold, $32,500,000; silver, $46,800,000; total, $79,300,000; or an increase of $1,600,000 over the output in 1881. For the first six months of 1883 the product is estimated at $16,250,000 gold,

$23,400,000 silver, and $39,650,000 total; the rate of production being assumed to be the same as in 1882.

Petroleum.—The production of crude petroleum in the oil fields of Pennsylvania and New York in 1882 was 30,053,500 barrels of 42 gallons each, worth, at an average spot value of 78⅞ cents per barrel, $23,704,698. During the first six months of 1883 the yield was 11,291,663 barrels, worth, at an average spot value of $1.00⅛ per barrel, $11,305,778. In addition to the quantitiy above stated, California produced in 1882 about 70,000 barrels.

Copper.—The production of copper in 1882 was 91,646,232 pounds, worth, at an average value of 17½ cents per pound in New York, $16,038,091. For the first half of 1883 the prodnction is estimated at 58,000,000 pounds, worth, at an average price in New York of 14.65 cents per pound, $8,500,000. The spot value of the copper at the point of production is a matter which cannot be stated with any accuracy; nor was any attempt made to ascertain the tons of copper ore mined. In 1882, 3,325,000 pounds of bluestone, worth, $191,187, were made; and in the first half of 1883 the manufacture of bluestone is estimated at 1,662,500 pounds, worth $95,593.

Lead.—In 1882 132,890 net tons of lead were produced, worth, at an average value of $95 per net ton on the eastern seaboard, $12,624,-550. For the first half of 1883 the production is estimated at 70,000 net tons, worth, at $90 per ton, $6,300,000. In this case, as with copper, it is impossible to state the average spot value of the lead, or the tons of lead ore mined. A very large proportion of the lead ore smelted is argentiferous, and is worked for its silver contents and not for the value of the lead, In the census year ending May 31, 1880, the amount of white lead corroded was reported at 123,477,890 pounds, worth $8,770,699.

Zinc.—The production of metallic zinc in 1882 was 33,765 net tons, worth, at an average value of 5.4 cents per pound in New York, $3,646,620. The production during the first six months of 1883 is estimated at 18,000 net tons, worth, at an average value of 4⅝ cents per pound in New York, $1,665,000. In addition to the spelter and sheet zinc made in this country, there is also a large manufacture of zinc oxide made directly from the ore. As in the case of copper and lead, it is impossible to fix an average spot value for the product, and the collection of statistics of zinc ore mined has not been attempted. In the census year 1880 the amount of zinc oxide manufactured, in-

cluding that made from scrap zinc, was reported at 20,121,761 pounds, worth $766,337.

Quicksilver.—In 1882 the production of quicksilver was 52,732 flasks (of 76½ pounds each = 4,033,998 pounds), worth, at an average price in San Francisco of 36⅞ cents per pound, $1,487,537. During the first six months of 1883 the production was 22,740 flasks (= 1,739,610 pounds), worth, at an average price of 35¼ cents per pound, $613,213. During the year 1882 700,000 pounds of vermilion were made in the United States, having a total value of $315,000.

Nickel.—The production of pure grain nickel in 1882 was 277,034 pounds, worth, at $1.10 per pound, $304,737. There was also a production of 50 per cent. copper-nickel alloy containing 4,582 pounds of nickel, worth $5,040. The total nickel production was therefore 281,616 pounds, worth $309,777. The only nickel reduction works in the United States were closed during the first half of 1883.

Cobalt.—The value of cobalt ores and matte for 1882 was about $15,000. The amount of cobalt oxide made was 11,653 pounds, worth $32,046.

Manganese.—The production of manganese ore in 1882 was 3,500 gross tons, and the spot value at the mines, estimated at $15 per ton, was $52,500.

Chromium.—The production of chrome iron ore in 1882 was about 2,500 net tons, worth, at an average price of $40 per ton in Baltimore, $100,000. The spot value cannot be ascertained.

Tin.—A trifling amount of tin ore was mined in 1882 and the first half of 1883, and production of metallic tin began on a small scale towards the close of the latter period.

Antimony.—The production of metallic antimony, so far as ascertained, was 60 tons in 1882, worth about $12,000.

Building stone.—It is estimated that the value of the building stone quarried in 1882 was $21,000,000.

Brick and tile.—It is estimated that the total value of the brick and tile made in the United States in 1882 was $34,000,000.

Lime.—There were 31,000,000 barrels (of 200 pounds each) made in 1882, having a total spot value of $21,700,000 at the kilns.

Cement.—The amount of artificial Portland cement made in 1882 was 85,000 barrels, worth, spot, $191,250. Of the cements manufactured from natural cement rock there were 3,165,000 barrels made,

worth, spot, $3,481,500. The total production of cement was 3,250,000 barrels, worth $3,672,750.

Clays.—Complete statistics of the quantity of fire and potters' clay mined in 1882 were not obtained. The value of the whiteware made was over $5,000,000.

Precious stones.—The spot value of the precious stones found in 1882, before cutting, was between $10,000 and $15,000; after cutting, between $50,000 and $60,000.

Corundum.—It is estimated that 500 tons were mined in 1882, worth on an average only about $12.50 per ton, crude and unground; total, $6,250. The value of the ground corundum manufactured during the same year was about $135,000.

Grindstones.—The value of the grindstones made from domestic rock in 1882 is estimated by leading dealers at $700,000.

Pumice stone.—There were 70 net tons quarried in 1882, worth about $1,750.

Phosphates.—The production of washed phosphate rock in 1882 by the land mining companies of South Carolina was 191,305 gross tons; spot value, $1,147,830. By the river mining companies, 140,772 gross tons; spot value, $844,632. Total, 332,077 gross tons; spot value, $1,992,462.

Marls.—In New Jersey, 1,080,000 net tons of marl were dug in 1882. The average spot value at the pits is 50 cents per ton, making the total $540,000. There was a small yield of marls in some of the Southern States, the amount of which has not been ascertained.

Gypsum.—The most complete statistics for 1882 are those of the output of Michigan, namely, 37,821 net tons of land plaster and 135,655 barrels (of 300 pounds each) of stucco. The manufacture of plaster-of-paris on the Atlantic seaboard was 525,000 barrels (of 250 pounds each), chiefly made, however, from Nova Scotia stone. Colorado produced 10,350 sacks (of 100 pounds each). The production of California and some other States was not ascertained.

Salt.—The amount of salt made in 1882 was 6,412,373 barrels (of 280 pounds each = 1,795,464,440 pounds), having a spot value of $4,320,140. During the first six months of 1883 the production is estimated at 3,206,186 barrels (= 897,732,080 pounds), worth $2,160,070, the rate of production being assumed to be the same as in 1882.

Borax.—The production in 1882 was 4,236,291 pounds, having a

spot value at the works of $338,903. For the first half of 1883 the output is estimated at 2,800,000 pounds, worth, spot, $224,000.

Sulphur.—Complete statistics were not obtained. The production in the census year was stated at 1,200,000 pounds, worth $21,000.

Barytes.—The amount of crude barytes mined in 1882 was 20,000 tons, worth at the point of production $160,000. The value of refined and ground barytes manufactured from the crude product above stated was about $440,000.

Mica.—The quantity of merchantable mica mined in 1882 is estimated by leading dealers at 75,000 pounds, worth $250,000. The production is rapidly increasing.

Soapstone.—The amount quarried in 1882 is estimated at 6,000 net tons, worth $90,000 at the quarries.

Quartz.—The amount of quartz mined in 1882 for glass making and abrading purposes is estimated at 75,000 net tons.

Asbestus.—Amount mined in 1882, 1,200 net tons, worth $36,000 at the point of production.

Graphite.—Amount mined in 1882, 425,000 pounds, worth, crude, at the point of production, $34,000. During the first six months of 1883 the production is estimated at 262,500 pounds, worth $21,000.

Carbonate of Soda.—Over 1,600,000 pounds were produced in 1882 from native deposits.

Asphaltum.—The production in 1882 was 3,000 net tons, having a spot value of $10,500.

Alum.—No statistics. In the census year the amount of manufactured artificial alum was reported at 39,217,725 pounds, worth $808,165.

Copperas.—The amount of copperas manufactured in 1882 is estimated at 15,000,000 pounds, worth $112,500.

The production of the following-named substances was insignificant: Apatite, arsenic, bismuth, infusorial earth, iridium, lithographic stone, nitrate of soda, ozocerite, platinum, strontia.

No reliable statistics were obtained of the following substances: Buhrstones, chalk, feldspar, fluorspar, mineral paints, pyrites (for acid manufacture), sulphate of soda, talc (other than "soapstone").

None of the following substances are known to have been mined in 1882, or in the first half of 1883: Carbons, cryolite, rottenstone, wolfram.

Totals.—It is impossible to state the total mineral product in any

form which shall not be open to just criticism. It is evident that the production statistics of such incongruous substances as iron ore, metallic gold and silver; the spot value of coal mined and the market value of metallic copper after having been transported hundreds of miles; the spot value of a crude substance like unground, unrefined barytes, and the value of a finished product like brick (in which the cost of manufacture is the leading item), such details cannot well be taken as items in a general summary. The statistics have been compiled with a view to giving information on those points which are of most interest and utility, and are presented in the form usual in the several branches of trade statistics. The result is that the values stated for the different products are necessarily taken at different stages of production or transportation, etc. Theoretically perfect statistics of mineral products would include, first of all, the actual net spot value of each substance in its crudest form, as taken from the earth; and yet for practical purposes such statistics would have little interest other than the fact that the items could be combined in a grand total in which each substance should be rated on a fairly even basis. The following groupings, therefore, are presented with a full realization of the incongruity of many of the items.

Values of the Metallic Products of the United States in 1882.

Pig iron, spot value	$106,336,429
Silver, coining value	46,800,000
Gold, coining value	32,500,000
Copper, value at New York City	16,038,091
Lead, value at New York City	12,624,550
Zinc, value at New York City	3,646,620
Quicksilver, value at San Francisco	1,487,537
Nickel, value at Philadelphia	309,777
Antimony, value at San Francisco	12,000
Platinum, value at New York City	1,000
Total	$219,756,004

Values of Some of the Non-Metallic Products of the United States in 1882 (*All Spot Values, except Chrome Iron Ore*).

Bituminous coal, brown cooal, lignite, and anthracite mined outside of Pennsylvania	$76,076,487
Pennsylvania anthracite	70,556,094
Crude petroleum	23,704,698
Lime	21,700,000
Building stone	21,000,000

Salt	4,320,140
Cement	3,672,750
Limestone for iron flux	2,310,000
Phosphate rock	1,147,830
New Jersey marls	540,000
Crude borax	338,903
Mica	250,000
Crude barytes	160,000
Chrome iron ore, value at Baltimore	100,000
Soapstone	90,000
Manganese ore	52,500
Asbestus	36,000
Graphite	34,000
Sulphur	21,000
Cobalt ore and matte	15,000
Precious stones, uncut	12,500
Asphaltum	10,500
Corundum	6,250
Pumice stone	1,750
Total	$226,156,402

Résumé of the Values of the Metallic and Non-Metallic Mineral Substances Produced in the United States in 1882.

Metals	$219,756,004
Mineral substances named in the foregoing table	226,156,402
	$445,912,406
Fire-clay, kaolin, potter's clay, common brick clay, terra-cotta, limestone used as flux in copper and lead smelting, iron ore used as flux in lead smelting, pyrites (for acid making), zinc white made directly from ore, marls (other than New Jersey), apatite, gypsum, tin ore, bismuth, arsenic, iridosmine, mill buhrstone and stone for making grindstones, lithographic stone, talc (other than "soapstone"), quartz, feldspar, fluorspar, terra-alba, chalk, crude mineral paints, nitrate of soda, carbonate of soda, sulphate of soda, native alum, ozocerite, mineral soap, strontia, etc.—certainly not less than	8,000,000
Grand total	$453,912,406

The grand total might be considerably reduced by substituting the value of the iron ore mined for that of the pig iron made; by deducting the discount on silver, and by considering lime, salt, cement, borax, etc., as manufactures. It will also be remarked that the spot values of copper, lead, zinc and chrome iron ore are much less than their respective values after transportation to market.

ON THE MANUFACTURE OF SULPHURIC ACID.

H. Pemberton, Jr., gives in the JOURNAL OF THE FRANKLIN INSTITUTE, 1883, vol. 115, p. 356, some results from the manufacture of sulphuric acid from brimstone, which illustrate the ratio between the nitre consumed and the chamber capacity; they are of interest, as they include a chamber system working with Gay-Lussac towers.

Pemberton calculates from the amount of the denitrated Gay-Lussac acid the quantity of nitre that passed through the chambers to every 100 parts brimstone, and finds 15·6 per cent. nitre, including 3·5 per cent. lost.

Hurter (1882, ccxlvi, 341) found in his theoretical examination of the sulphuric acid process, that the product of the chamber space and nitre consumed, approaches a constant figure, which represents the chamber capacity corresponding to one per cent. nitre consumed, Gay-Lussac towers not being used. The chamber capacity and nitrogen compounds present are indirectly proportional to each other, provided that the loss of sulphur is equally great, and the acid produced is of uniform concentration. When working with weak acid, a smaller chamber capacity is required. (See Wagners' *Jahresbericht*, 1882, p. 240.)

HURTER'S RESULTS (PYRITES ONLY.)

	Cubic feet capacity per lb. sulphur.	Nitre consumed per 100 lbs. sulphur.	Product of nitre consumed and chamber capacity.	Acid from 100 lbs. sulphur.	Sp. gr. of the acid.
A	32·3	10·0	323	431	1·55
B	29·8	11·2	334	392	1·65
C	24·5	12·0	294	345	1·65
D	22·3	13·7	305	386	1·65
E	22·8	9·5	217	405	1·50
PEMBERTON'S RESULTS (BRIMSTONE).					
1	26·8	10·0	268		
2	29·8	9·0	268		
3	35·7	8·0	285		
4	19·2	15·6	300		

The above results from Hurter are yearly averages, obtained from

five important English works burning pyrites. Pemberton's results are derived from a set of chambers running on brimstone only, and in which, unfortunately, no positive statements in reference to loss in sulphur and concentration of acid are given, and which, therefore, do not allow of comparison with the much more certain results of Hurter. It is self evident that the constant for brimstone must be lower than that for pyrites.

In A and E the acid is much weaker; in A the yield is the best; in E the chamber capacity is the smallest. System 4 worked with Gay-Lussac with a loss of 3·5 per cent. nitre.—*Dingler's Journal.*

BRONZE FOR TELEPHONE LINES.

The careful investigation instituted by E Van Der Ven of the Teyler Foundation, on wires made of the metallic alloys, known as phosphor-bronze and silicon-bronze, are the more welcome on account of the discussions had, particularly at the Paris Electrical Congress, concerning the practicability of their use. The wires experimented with contained, according to chemical analyses made for him by M. Van Eyndhoven, in the case of the phosphor-bronze: copper, 95·5 per cent; phosphorus, 2·6 per cent., with small quantities of tin, manganese and silicic acid; in the silicon-bronze: copper, 92·2 per cent; silicium, 0·91 per cent., together with small quantities of tin, manganese and antimony.

The practical results of Dr. Van Der Ven's researches are, that phosphor-bronze has about 30 per cent. of the conducting power of copper, silicon-bronze about 70 per cent., while the steel as used in wires has only about 10·5 per cent. Comparing their tenacity, as also very carefully determined by him, with that of steel, he finds that a wire of the latter material, of 2 mm. diameter, with quadruple security and the conventional sag of .7 m., can have a stretch from pole to pole of 130 m., while the stretch, under the same conditions, of a wire 1 mm. in diameter would for phosphor-bronze be 106 m., for silicon-bronze 91 m. These alloys, with a diameter of 1·18 and of 0·77 mm. respectively, have the same electrical resistance as the steel wire of 2 mm. diameter. "The relatively short stretch which in general increases the expense of construction and maintenance, is less costly in cities, where at short distances the roofs of buildings offer points of

suspension for telephone wires. It goes without saying that the bronze wires are preferable to those of steel, whose resistance demands a much larger section; the more, since the network of lines suspended in the air cannot be counted among the ornaments of a large city." To this result we may add the statement made by M. Bede at the Congress. A phosphor-bronze wire of .8 mm. (costing, too, the same as steel of .2 mm.) would, on account of its high elasticity, coil up before it has fallen 4 m. from its original position—so rapidly that on breaking it would ordinarily not strike the ground, and hence would be less dangerous. On account of non-oxidation there is no loss of diameter.—*Musée Teyler and Electrotech. Zeitsch.* M B. S.

FRANKLIN INSTITUTE.

INTERNATIONAL ELECTRICAL EXHIBITION IN PHILADELPHIA, TO OPEN TUESDAY, SEPT. 3, 1884.

The attention of all persons interested in the generation and applications of electricity is respectfully invited to the Electrical Exhibition, to be held in Philadelphia, United States of America, commencing on Tuesday, Sept. 3, 1884, under the auspices of the Franklin Institute of the State of Pennsylvania for the promotion of the mechanic arts.

From the eminent reputation of this institution, coupled with the fact that the projected exhibition will be the first in America exclusively devoted to this important and progressive branch of science, the above announcement has attracted unusual interest throughout the United States, and the exhibition will undoubtedly afford an admirable opportunity of witnessing a representative display of American discovery and invention in electricity.

To increase its scientific and industrial importance, as well as to add to its attractiveness, it was determined, shortly after its inception, to give it an international character; and, the importance of the project having been properly represented to the Congress of the United States, an act was passed, which, having received the signature of the President of the United States, is now the law.

This official recognition provides for the admission into the United States, duty free, of all articles for exhibition only.

The text of this Act of Congress is as follows:

"WHEREAS, The Franklin Institute, of the State of Pennsylvania,

for the promotion of the Mechanic Arts, propose to hold an exhibition of electrical apparatus, machinery, tools and implements, and other articles used in scientific and mechanical, and manufacturing business and investigations; and

"WHEREAS, It is deemed desirable to promote the success of such an exhibition by all reasonable encouragement, in order that it may be made useful for the promotion of knowledge; therefore be it

"*Resolved*, By the Senate and House of Representatives of the United States of America, in Congress assembled, that all articles that shall be imported for the sole purpose of exhibition at the exhibition to be held by the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts in the City of Philadelphia in the years 1883 or 1884, shall be admitted without payment of duty or customs fees or charges, under such regulations as the Secretary of the Treasury shall prescribe: *Provided*, That all such articles as shall be sold in the United States or withdrawn for consumption therein at any time after such importation, shall be subject to the duties, if any, imposed on like articles by the revenue laws in force at the date of importation: *And provided further*, That, in case any article imported under the provisions of this joint resolution shall be withdrawn (for) consumption, or shall be sold without payment of duty as required by law, all the penalties prescribed by the revenue laws shall be applied and enforced against such articles and against the persons who may be guilty of such withdrawal or sales."

It remains only to add at the present time that no effort will be spared by the Franklin Institute to secure a large and important representation of the progress of foreign countries, and that the most liberal provisions will be made to place European and American exhibitors on a fair and equal footing.

The subject of electricity and its applications, is at present attracting an unusual amount of attention, and the exhibition, side by side, of the best achievements of Europe and America, cannot fail to be in the highest degree instructive.

The necessary details respecting the classification of exhibits, applications for space, the regulations for the entry of articles for competition, advices as to the best modes of transporting articles intended for the exhibition, the arrangements for the reception and safe disposition of goods, and other needful information relating to the subject of the exhibition, will shortly be made public. A committee of the

Franklin Institute will be appointed to furnish information to exhibitors from foreign countries regarding the entry of goods intended for exhibition at the Custom House in Philadelphia. Intending exhibitors, desiring such information with promptness, are invited to communicate with the

Secretary Franklin Institute, Philadelphia, U. S. A.

Book Notices.

THE ORES OF LEADVILLE AND THEIR MODES OF OCCURRENCE, as illustrated in the "Morning" and "Evening Star" Mines, with a chapter on the Methods of their Extraction as practiced at those Mines. By Louis D. Ricketts B. S., *Ward Fellow in Economic Geology of the College of New Jersey.* With five plates and one colored lithograph. Princeton, 1883.

The first part of this work, or rather all except the descriptive part, including the methods of mining (called by the author "Methods of *Extracting* the Ores,") formed a thesis for the degree of Doctor of Science from the College of New Jersey.

It would be well for the standard maintained by the higher institutions of learning in this country if bequests for fellowships similar to the Ward fellowship, under which the work for this memoir was undertaken, were more common in our universities. By the terms of this fellowship its holder must devote a certain part of the year to the study of one or more of the mines in the West (if the writer be correctly informed, in Colorado.) Such studies are not only admirably adapted to test the thoroughness of the student in the many diverse branches of science which they involve, but they are of the greatest practical utility to all American and foreign geologists and mining engineers, since they reveal the methods by which important problems in mining have been solved under those conditions of labor, transportation, material and value which only obtain in our semi-settled domain.

The author acknowledges his obligations to Emmons, and presents his facts as further illustrations of the accuracy of the latter's theory of structure, in which he himself fully concurs, in all but a few minor particulars. After a short subdivision treating of the "General geology" and the "Position of the deposits," he proceeds to give in detail the "Geological structure at the mines." This is a very painstaking

piece of work, very clearly illustrated by the horizontal projection of the two ore bodies of the mines mentioned in the title (Plate II); vertical sections through the shaft of the "Morning Star" (Plate III), and of the "Evening Star" (Plate IV).

The boundaries of the White Porphyry, Ore, Blue Limestone, Gray Porphyry (Blue Limestone), White Limestone and Quartzite which occur in the order given, proceeding from above downwards, are very clearly made out by the aid of careful observations, and references to the plates already referred to, as well as to a color plate (I), which gives in three figures, and in a manner striking to the eye, the irregular boundaries of the three various strata in vertical section. A detailed description of the rocks follows, accompanied by analyses of the two limestones and the white porphyry. The theory of ore currents is very succinctly and strongly stated. It is made very clear that the mode of occurrence of the ore is such as might have been produced by the filling up of the bed of a subterranean stream flowing, generally speaking, in contact with the present under surface of the white or upper porphyry. The minerals, both pure and impure, constituting the gangue are briefly stated and physically and chemically described. Under the head of the "Ores" the author for the first time makes an exception to the rule of extreme caution which he has imposed on all his statements. He thinks "there can be no doubt that the lead was all originally deposited in the limestone horizon as the sulphide."

Many experienced colleagues, both geologists and mining engineers, will not be able to follow him so far, nor does there appear any good reason why acid solutions charged with lead salts should not have deposited sulphates and chlorides and carbonates in the body of the limestone, as well as sulphides. It is also hazardous to assert that only "small amounts of all the metals were carried off in solution by the oxidizing waters," or that they were "to a large extent redeposited in the gangue." What may have been the extent to which these actions were carried we have no means of knowing, but there are no data at hand which will enable us to limit them, especially if the supply of waters charged with metal salts be supposed to have continued for a great lapse of time.

In the same chapter describing the Galena, Dr. Ricketts drops twice unconsciously out of the rigorously exact and scientific language which he has heretofore employed into the familiar parlance of the

miners when he speaks of streaks of galena running through "black iron," and "surrounded by *iron*" (p. 31). Under the head of the "Chloride of Silver" he is somewhat disappointing to the reader in the sentences following that in which he says it is easy to explain where the silver missing from the carbonates has gone. He shows so many places where it has gone, *i. e.*, into the porphyry, the limestone and "the vein matter deep down in the current," as to render it extremely probable that a still larger supply than all may have gone into the seas which receive the drainage of the waters which he makes the transporting agent (though he does not mention them). Another slight omission seems to be the "remarkable deposition of cerargyrite in the white porphyry of the Evening Star. Except in the statement above and the incidental allusion to the silver in it, he does not give an adequate description of this very interesting phenomenon.

In describing the deposition of the vein materials, his theory of the "chemical interchange or actual replacement" seems unquestionably sound, but it is not clear how he intends the theory to be applied to the deposition of lead as the sulphide previously noted, nor in what form he supposes this metal to have arrived at its present place. The expression "oxidizing waters," which occurs on p. 45 and in various other places, does not specify clearly what kind of reaction on the carbonates of iron and manganese is meant. It is not stated what was probably the constitution of the "mineralized waters" carrying those metals, whereby they deposited them and took in return lime and magnesia to form with their acids more soluble salts.

The second part, which treats of the machinery and methods of mining, the construction of the plant, the cost of the items and the value of the product, is so complete and elementary in its descriptions as to constitute a valuable work of reference, and a text for the instruction of students in mining engineering.

Viewed as a whole, the memoir is highly creditable to the author, and to the college which crowned it by the highest reward for work done in its gift.

The style is generally clear, if not elegant; the printing neat, and the proof-reading generally carefully done, but there are a few not very important exceptions to the usual excellence in both these particulars, such as "prominant" (p. 21), "decomposition" (p. 38), the "more pure variety," etc.

The plates deserve to share the above commendation, though, in the judgment of the present writer, the colors in the color plate and the symbols on Plates III and IV to indicate white limestone might have been selected with more regard to the conventional uses of colors and lining for different rocks.

The pamphlet is a quarto; contains 68 pages of letter-press besides the four plates just alluded to, and is an important and valuable addition to our technical literature. P. F.

THE GEOLOGY OF CHESTER COUNTY, after the surveys of Henry D. Rogers, Persifor Frazer, and Charles E. Hall. Edited by J. P. Lesley. 1883.

In its typography, this volume is an improvement upon some which have preceded it, yet the errors are more numerous than they should be, and evidences of careless editing are not wanting. The well-known Chester Valley, besides that name, is called (p. 14) Limestone Valley of Downingtown (p. 16) Downingtown Valley, the Chester Valley as it is commonly called, (p. 98) Downington Valley, (p. 284) "the Limestone Valley in which is the King of Prussia."

(P. 179) "From the *Philadelphia* gneiss hills across to the Reading hills." Evidently the syenitic gneiss hills S. of the S. Valley hill are meant and not the Philadelphia gneiss of p. 40, etc. (P. 48) "The mica and hornblende *blackened* by iron."

A large part of the volume is made up of quotations from Rogers. Whatever doubts may have been cast upon some of Rogers' theories of structure, he stands preëminent as a most careful, conscientious observer of geological facts. These extracts coming, as they do, in this portable form, are valuable, but no effort seems to have been made to eliminate or point out errors; thus (p. 40), we find "Haddon," probably intended for Radnor, Callwell for Colwell, Matzan for Mattson, etc. (p. 100), nor do Rogers' observations seem to have been compared on the ground. This leads to what appear to be curious blunders on pp. 39 and 100. (P. 39), "The long belt of Serpentine starts in the *Talc-mica slates*, 1 mile S. E. of Paoli, more than 400 yards north of the contact of *gneiss* and *slate*."

What Rogers wrote (I, p. 78) was, "Our line now crosses Crum Creek . . . and here the gneiss is in close proximity to the southern margin of the long belt of stratified serpentine, which origi-

nates in the *talcose primal slates*, about one mile S. E. of the Paoli, and more than one-fourth of a mile N. of the *gneiss* at that point."

Throughout C^4 the term "*talc mica slates*" is, with other terms, applied to the rocks of the S. Valley hill, while Rogers was writing of his *altered primal slates* which in C^4 are classed among the *gneisses*, both in the text (p. 283, etc.) and on the map. The map does not show the hydromica schists south of the serpentine, and on the contrary, on p. 60 we find, "The range of serpentine and limestone exposures limit it" (hydromica schist belt) "through Easttown," etc.

P. 100. "Passage beds, from the *talc mica slate* into limestone, are also recognized and described by Mr. Rogers, on p. 165, as visible at Callwell's (Colwell's) furnace at the mouth of Matzan's (Mattson's) run, opposite Conshohocken, on the Schuylkill, thus:

1. Talc slate, vertical, on the *N. slope* of the *South Valley hill*, then going *north*. 2. Limestone. 3. Talcoid nacreous slate 100′. 4. Limestone impure 50′. 5. Talcoid garnetiferous slate. Limestone, magnesian, say, 200 feet S. of Conshohocken bridge."

A glance at the map in C^6 will show that the north slope of the S. Valley hill is half a mile *North* of the Conshohocken bridge.

What Rogers really wrote (I, 165) is: "A transverse section at Caldwell's furnace from the *primal slates* into the auroral limestone displays: 1. Talc slate on the *north slope* of the *bounding ridge*," and then as above. Now this *bounding ridge* was evidently the great gneissic ridge, with Rogers' altered primal slates forming its northerly slope, his section *ending* at the *southerly* slope of the S. Valley hill.

An inspection of the localities, or even a careful reading of Rogers, would have prevented such blunders.

P. 14. "South Valley hill, or hydromica schist belt . . . the Pennsylvania Railroad runs along the ridge from Radnor to Frazer, about 13 miles," but on p. 39, "West of Morgan's corner" (the old name of Radnor Station) "*gneiss*, massive, granitic," and p. 282, "The fragments of rock just N. of Radnor Station show a finely laminated gneiss." The table of elevations (p. 14) shows very clearly that for some distance W. of Radnor the railroad is descending the gneiss hill. P. 42, describing this gneiss belt, "Garnets are entirely absent," while on p. 286, speaking of the same belt in Easttown, "The whole of the southern part of the township is composed of syenitic granite . . . *with garnets.*"

The map of Mr. Hall, alluded to in the text, is omitted, except as a

mere page sketch of no possible value in a complicated region, and that of Dr. Frazer, of a scale one inch to two miles, with the coloring in dispute, and one long line which "has no geological value whatever, but is merely a temporary expedient" (p. vi), is not a great advance over that published by Rogers twenty-five years ago. All the gneisses and mica schists south of the S. Valley hill, including the well-defined rock, Rogers altered primal, are embraced in one color. The trap (pp. 87 and 218) on the N. side of the serpentine, Easttown, is not upon the map.

In papers published in the *Proc. Min. and Geol. Sec. Acad. Nat. Sci.*, 1880–81, pp. 9 and 28, Theo. D. Rand asserted that the serpentine in Radnor and Easttown, instead of outcropping in lines which, if prolonged, would meet, as mapped by Hall,* and by Dr. Frazer, in the present volume, had an echelon structure, the strike being from S. 40 W. to S. 60 W., while a line joining the exposures would be nearly E. and W., and called attention to Rogers' description of a similar structure of the trap dykes north of the serpentine quoted in C^4, p. 87. A map of the outcrops was published with the text. If these outcrops are as stated, the fact is of interest; if they are not, the error should have been corrected. In a criticism of the map by Dr. Frazer, in 1883,† no allegation of error in this particular is made.

In the same papers are described outcrops of a sandstone which Mr. Rand thought was identical with the eurite of Barren Hill, etc., admitted to be Potsdam, and also a sandstone resembling the Potsdam of the North Valley hill, found on the north slope of the South Valley hill. These rocks do not appear to have been examined, but the broad statement is made, p. 34: "The quartzite failed altogether on the south side of the valley;" and page 124: "But no Potsdam sandstone has been detected anywhere along the south edge of the limestone area. Rogers did not overlook the sandstone along the south side of the Chester valley (Vol. I., p. 166). The other exposures were probably not visible when his survey was made.

It is doubtless true, as Prof. Lesley states in his letter of transmittal, that Dr. Frazer has studied the region with thoroughness, and has recorded a large number of observations, taking into consideration the very limited time devoted to the region—three days to a township (p. xx.); but that this report adds much to our knowledge of the

* *Proc. A. P. S.*, vol. xviii., p. 105.

† *Amer. Nat.*, xvii., No. 5, p. 523.

region may well be doubted. In the letter of transmittal may be found an explanation. "Little more can be said than that the first geological survey did something to reveal the structural geology of the Philadelphia Baltimore belt, and that the second geological survey has added its mite to the revelation, but that a great deal more light must be thrown upon it before we can congratulate ourselves upon a proper and satisfactory knowledge of it. . . . . We have an abundant knowledge of all the kinds of rocks . . . ne region . . . . . merely as minerals . . . . and there is quite as much information respecting their localities in Delaware and Chester ounty as there is respecting the localities of coal in any western county of the State. It would be quite as absurd to ask of the . . . . survey . . . . to do the work of opening up continuous outcrops of these minerals (and we must presume of mapping those that are known) as it would be to ask the survey to prove by actual digging the continuous outcrops of the Pittsburg . . . . or the Sharon coal beds. What the State provides through the geological survey is such general investigation of the field, such an examination of localities as will result in a *just and practical understanding of geological structure.*"

In so complicated a region how is this end to be attained without exactly what Prof. Lesley says it is absurd to ask? His admission that it has not been attained or even approached renders the comparison hardly fair between a region in which the leaves of the geological book are as if it had been struck on its edge with a steam hammer, with one in which they are almost as smooth and regular as in a book fresh from the binder's hands.

Admitting the difficulty of the region, admitting the fact that the rocks vary greatly, and that a determination of geological age must be left to the future, is it not the only true plan to delineate on a map of ample scale the formations *as they are*, much as one would in other branches of science plot observations upon a series of abscissæ and ordinates, hoping thereby to get a curve and discover a law? Is there any better way? T. D. R.

Electric Properties of Collodion.—J. Seure states that collodion, in thin sheets, is negative towards all other bodies. In interpreting the therapeutic effects of collodion, account should be taken of its electric power. Gutta percha, when it is electrified, presents modifications which are analogous to those of collodion.—*Comptes Rendus.* C.

Electric Furnace.—The electric furnace possesses two great advantages—the temperature which can be produced is only limited by the refractory resistance of the crucible, and the heat is developed in the materials which are to be melted, without first traversing the recipient. Six pounds of forged iron were submitted for twenty minutes to the action of the arc, and the metal was then poured into a mould. It was found to be crystalline and could not be forged. This difficulty may be remedied by adding a little manganese before pouring out; but the reason of this action is not understood. Three-quarters of a pound of copper were melted in charcoal dust for an hour, at the end of which time all but three-quarters of an ounce had been vaporized. The persons who were present did not perceive any disagreeable effects from the atmosphere which they were obliged to breathe. Eight pounds of platinum were entirely melted in about a quarter of an hour. A half pound of powdered tungsten was submitted to the action of the electric arc, in a clay crucible. Very dense fumes escaped, and a cavity about a half inch deep formed at the summit. The metal appeared to have been melted to only a very slight depth below the cavity. The unmelted portion was covered with very beautiful crystals, which, when examined by a microscope, were found to be prismatic, but they were not very uniform. The crystals were evidently formed by the slow cooling of the distilled vapor. Experiments were tried with various other metals, showing that the quantity of any given metal which can be completely melted in an electric furnace, and the time required for the fusion, depend upon the interval between the point of fusion and the point of vaporizing, as well as upon the thermal conductibility of the metal. Thus it happens that platinum is melted much more easily than steel, and in a much greater quantity, for the same expenditure of energy.—*L'Electricien*, Jan. 1, 1883. C.

Rapid Formation of Mineral Veins.—Dr. Fleitmann has found that the formation of mineral veins requires much less time than has usually been supposed. About two years ago he filled a ditch with clay which contained iron. Having had occasion to open the ditch again, he discovered, to his great surprise, that the clay had entirely changed its character, and had become white. Moreover, it was divided in various directions by fissures, with sections varying from $\frac{1}{20}$ to $\frac{1}{8}$ of an inch, which were filled with compact iron pyrites. He supposes that the oxide of iron in the clay was changed into sulphate of iron by contact with water which contained sulphate of ammonia.—*Les Mondes*, March 4, 1883. C.

Ingenious Rat Trap.—Capt. Godreuil had a ship infested with rats, which devoured his provisions and his rigging. He took an empty flour barrel, leaving only three hoops, one at the top, one at the bottom, and one in the middle, so that the rats could not climb up on the outside. He placed above it a cover, with a diameter a little less than that of the barrel, and supported it on two pivots, so that it would rock under the least weight. Under the centre he placed a hook, to which he suspended a bit of toasted bacon; finally, a strip of plank, forming an inclined plane, extended a little above the barrel. When the rats reached the top of the plank they leaped upon the cover, which rocked under their weight, and they fell to the bottom of the barrel, from which they could not escape, the staves being closely joined, and smeared with tallow.—*Les Mondes*, Feb. 10, 1883. C.

Bridge Travel in London.—Proposals having been made for building a new bridge over the Thames, statistics have been collected to show the amount of travel over the present bridges. The following table shows the average daily travel over a few of the principal bridges:

London	110,525	pedestrians,	22,242	vehicles.
Black Friar's	79,198	"	13,875	"
Westminster	44,460	"	11,750	"
Waterloo	32,815	"	10,370	"
Southwark	25,507	"	3,340	"
Vauxhall	17,828	"	5,453	"
Charing Cross	16,130	"		
Chelsea	14,500	"	2,338	"
Battersea	10,260	"	1,342	"

The addition of the other bridges gives a total of 384,042 pedestrians, and 75,325 vehicles.—*Dingler's Jour.*, Jan. 24, 1883. C.

Factory Chimneys.—It is well known that the round form is the best for the chimneys of factories and workshops. It facilitates the escape of the smoke, and gives less hold for the wind, besides requiring less material for construction. Round chimneys, however, are more difficult to build, so that in some places the want of workmen who are skilled in this kind of construction leads to the adoption of a square or octagonal section. In order to facilitate the erection of round chimneys, M. Houzen, of Nüremberg, prepares materials cut in the form of wedges, corresponding with the radius which the chimney is to have, so that the construction presents no kind of difficulty.—*Chron. Industr.*, Feb. 18, 1883. C.

Spectroscopic Estimates of Atmospheric Absorption.—Cornu has been led, by his investigations of the atmospheric absorption of the ultra-violet rays, to examine the relation between that phenomenon and the absorption of the visible rays. His attention was especially directed to Brewster's dark bands, which are generally known as telluric rays, the intensity of which increases with the thickness of the atmosphere which they traverse. He finds that the amount of absorbing matter may be estimated by the sines of the altitude from the sun at which a telluric ray has the same intensity with a metallic ray. Hence may be deduced a very simple method for estimating, at any moment, the total amount of vapor which exists in the atmosphere.—*Comptes Rendus*, Nov. 6, 1882. C.

Azotine.—M. Heddebault has discovered a method of preparing soluble wool from tissues in which wool and cotton are combined. When subjected to a current of superheated steam, under a pressure of five atmospheres, the wool melts and falls to the bottom of the pan, leaving the cotton, linen, and other vegetable fibres, clean and in a condition suitable for paper making. The melted wool is afterwards evaporated to dryness, when it becomes completely soluble in water and is called azotine. The increased value of the rags is sufficient to cover the whole cost of the operation, so that the azotine is produced without cost. It contains all its nitrogen in a soluble condition and can, therefore, be compared to dried blood, which is worth 2.50 francs per kilogramme of nitrogen. M. Ladureau regards this discovery as one of great interest for agriculture and mechanical industry.—*Soc. Industr. du Nord.* C.

Magnetism of Steel at Different Temperatures.—Prof. Poloni has been experimenting upon the influence of heat on the permanent magnetism of steel. He finds that the diminution of magnetic intensity, by the increase of temperature in the steel bar, has no rigid relation to the increase of electric resistance in the metal itself. Indeed, while the permanent magnetism diminishes with increasing rapidity up to a temperature of about 200° (328°F.), and then less rapidly up to 300° (508°F.), becoming inappreciable at red-heat, the electric conductibility of the iron diminishes uniformly with the increase of temperature.—*Chron. Industr.*, Jan. 7, 1883. C.

Electric Currents Produced by Nitrates.—M. Brard has communicated some investigations to the French Academy, which give the following results: 1. On plunging a red-hot carbon into a bath of melted nitrate an energetic current flows from the bath into the exterior circuit. 2. The melted nitrates become very fluid, and like greasy bodies lubricate the heated bodies with which they come in contact. 3. In order to obtain a current it is not necessary to plunge the carbon into the nitrate bath, but it suffices to place a metal capsule containing some grains of the melted nitrate upon the burning carbons. M. Brard is continuing his experiments with a view to apply them practically in the production of light and heat.—*Les Mondes*, Jan. 13, 1883. C.

Photographs of the Great Comet.—Six photographs of the late comet, which were taken at the observatory of the Cape of Good Hope by D. Gill, were sent to the Paris observatory and presented to the Academy by Admiral Monchez, who pronounced them the finest that he had seen. The stars in the centre of the image are reduced to a point of remarkable sharpness, in spite of the very long duration of the exposure, which amounted to 140 minutes for the sixth negative. More than fifty stars are seen through the tail of the comet. The slight increase of diameter, which is observed in the stars remote from the centre, is due to the employment of an apparatus with too short a focus. The fine result is explained by the well-known skill of the photographer and the purity of the South African sky. The success of the experiment encourages the hope that it will soon be possible to make excellent celestial charts by photography.—*Comptes Rendus*, Dec. 26, 1882. C.

Absorption by the Humors of the Eye.—M. de Chardonnet finds that most of the rays of the solar spectrum traverse the cornea and the vitreous humor, but the spectrum of the crystalline lens corresponds exactly to the visible spectrum, and he thinks that lens has the physiological function of intercepting all the ultra-violet rays. He was, therefore, led to inquire whether our failure to see those rays is owing to an insensibility of the retina or to the fact that the rays do not reach it. Dr. Saillard furnished him with two subjects, who had had the crystalline lens removed in operations for cataract. The retina, in both cases, was as sensitive to the ultra-violet rays as to the visible rays.—*Comptes Rendus*, Feb. 19, 1883. C.

Age of Vegetables.—It is generally thought that the age of trees may be ascertained by the number of concentric ligneous layers, each layer corresponding to the growth of a year. This principle is not applicable to tropical and equatorial trees, as is shown by the following fact. M. Charencey visited the ruins of Palenque, in Mexico, in 1859 and in 1881. On one occasion he cut off the branch of a shrub, which he judged by its size to be about eighteen months old, but he found eighteen concentric layers. On his first expedition his party cut down several trees, in order to get at the pyramid. New shoots have since grown, which must, of course, all be of the same age, twenty-two years. On one of them M. Charencey counted 230 concentric layers.—*Les Mondes*, Feb. 10, 1883.

Modifications of Glass at Moderate Temperatures.—Messieurs Crafts and Pernet have presented some recent communications to the French Academy, relatively to the changes which thermometers undergo when they are heated for a long time. In manufactories of printers' ink, where oils are heated to a temperature of 270° (538°F.) for many days, the most accurate thermometers often become so changed as to indicate errors of ten or more degrees. J. Salleron calls attention to similar changes at much lower temperatures. The areometers which are employed in sugar refineries where molasses is treated by osmosis, are plunged for many days in liquids which are heated to 95° (203°F.). Although this temperature is below the boiling point of water, it is sufficient to completely modify the areometers and to soften the glass enough to make them untrustworthy.—*Comptes Rendus.* C.

Cement for Glass.—A concentrated solution of bichromate of potash and glue makes an excellent cement for repairing articles of broken glass. After covering the fractured surfaces with this solution they are brought together and exposed to the action of the sun. This cement resists boiling water.—*Gaceta Industrial*, March 10, 1883. C.

Detection of Wood Fibres in Paper.—As wood changes under the influence of the air, growing brown and consequently diminishing the durability of the paper in which it has been employed, it is of great importance, both for the dealer and for the consumer, to be able to ascertain whether a given sample of paper contains woody fibres or not. For this purpose a solution of sulphate of aniline, or a mixture of one part sulphuric acid, three parts nitric acid may be employed. Either of these solutions produces immediately a yellow color upon the paper if it contains wood, the depth of the yellow shade increasing as the proportion of wood increases.—*Chron. Industr.*, Feb. 25, 1883.

Relation of Electromotive Force to Velocity of Rotation.—In his recent lectures at the College of France, Maurice Levy has given equations which rigorously define the electric field and the magnetic field of a dynamo-electric machine in its permanent state. Although the equations cannot be integrated, he has deduced many consequences, among which he calls especial attention to the following: The electromotive force of a dynamo electric machine is not, as has been commonly thought, proportional to the velocity of its coils; it can only be expressed by an infinite series, arranged according to the integral powers of that quantity.—*Comptes Rendus*, Nov. 6, 1882. C.

Hollow Magnets.—While Preece has found that there is no difference in the conducting power of lightning rods of various forms, Holtz has concluded that solid steel bars do not form so good permanent magnets as tubes, because the core acts as an armature joining the two poles. In experimenting to test his hypothesis, he magnetized rods and tubes to saturation, and found that the magnetism of the tube showed an excess of more than 50 per cent. After waiting six months, he subjected the same magnets to new tests, in order to find which retained the magnetism best. He found that the magnetism of the solid was to that of the hollow magnets, in one case as 1 : 2·5, in another as 1 : 2·9.—*Wied. Annalen* C.

Tail of the Great Comet of 1882.—Terby, in concluding the report of his observations upon the aspect and positions of the last great comet, concurs in the opinion of Cruls, that the appearances may be explained upon the hypothesis of a triple tail, of which the three elements were almost wholly superposed in September, and were gradually unfolded before terrestrial observers during the months of October and November. One of these tails was directed almost exactly in the line of the prolonged radius vector, as in the case of Donati's comet. The others were more curved.—*Bul. de l'Acad. de Belg.*, 1883. C.

Spectral Lines of Cruls' Comet.—Cruls, in a letter to Faye, gives the mean of numerous micrometric measurements of the spectral lines, and also of the lines which were given by the blue flame of a Bunsen burner in which he had introduced chloride of sodium:

Comet.	Burner.
38*t*·15	37*t*·86
42 ·12	41 ·60
50 ·43	50 ·00
62 ·58	62 ·30

The measurements are given in turns of the micrometer (*t*). The spectrum of the tail was like that of the nucleus, but the lines were much fainter.—*Comptes Rendus*, Nov. 6, 1882. C.

Displacement of Spectral Lines in the Late Comet.—In examining the comet of 1882, by a spectroscope of a single prism, Thollon and Gouy were able not only to prove the existence of the bright lines of sodium, but also their displacement towards the red, a displacement which they estimated at $\frac{1}{4}$ or $\frac{1}{5}$ of the interval between the two sodium lines D_1 and D_2. They concluded that the comet was removing from the earth at that moment with a velocity of from 61 to 76 kilometres per second. They looked with great interest for an opportunity of verifying their conclusions, but nothing was then known regarding the comet's orbit. M. Bigourdan has since found that the comet was then moving with a mean velocity of 73 kilometres per second. This accordance shows the certainty of spectroscopic indications in such cases. It also shows that the vapors of sodium, which surrounded the cometary nucleus, followed the same path and made part of the constituent elements of the comet. It also confirms, in a remarkable manner, the law of the change of wave lengths produced by the movement of the luminous body.—*Comptes Rendus*, Feb. 5, 1883. C.

Thickness of Electric Layers.—M. Lippmann has pointed out some numerical applications of Helmholtz's theory of double electric layers. He shows, at first, that the hypothesis of the double layer conducts to a parabolic relation of the second degree, between the capillary tension and the difference of potential; experiment verifies this deduction. Admitting the hypothesis of the double layer, its thickness may be calculated by means of the well-knwn formula which gives the capacity of a thin layer as a function of its thickness. The thickness is thus found to be $\frac{1}{35000000}$ of a millimetre, which represents the distance between the mercury and the superposed water.—*Chron. Industr.*, Jan. 7, 1883. C.

Light Motors.—In an excellent article which appeared in a late number of the *Aéronaut*, David Napoli, President of the Société de Navigation Aérienne, examines the comparative desirability of steam and electric motors for propelling long balloons. He found that a twenty-horse steam engine, working for ten hours, would consume 200 kilogrammes of coal and 1,400 kilogrammes of water. An electric engine of twenty-horse power, with all its supplies for ten hours' service, would weigh about 1,400 kilogrammes, which is less than the bare consumption of material in the steam engine, leaving out of the question the weight of the generator and of the mechanism of transmission.—*Chron. Industr.*, April 15, 1883. C.

Explosion of an Open Kettle.—At a factory in Neusalz, a large cast iron wash kettle was used to hold water, into which melted iron was allowed to flow, in a moderate stream, for making iron shot. On October 23, 1882, one of the workmen by mistake allowed the iron to flow too rapidly. There was a sudden development of steam, which threw out a part of the water, frightening the laborer and causing him to drop his ladle, so that about 20 kilogrammes (44 pounds) of melted iron fell at once into the water. There was an immediate rapid outburst of steam and a loud explosion, which shattered the kettle into fragments, tore up the wood work, threw the workman nearly eight feet backwards and broke his right leg. Only very small pieces of the kettle were found where it stood; some of them were thrown to a distance of about fifty feet.—*Dingler's Jour.*, March 7, 1883. C.

An Arabic Celestial Globe of the Eleventh Century.—In the philosophical cabinet of the Royal Institute of Florence, many of the instruments of Galileo and other students of astronomy and physics are preserved. Among them is an Arabic celestial globe, of which F. Meucci has published an interesting description. It has not been long in possession of the Institute and no one suspected its antiquity until recently. The one which is in the Borgian Museum, at Velletri, which was described by Assemani, in 1790, and which dates from the year 1225, has hitherto been regarded as the oldest. There are two others of the same century, one of A. D. 1275, owned by the Royal Asiatic Society of London, the other of A. D. 1289, in the mathematical Saloon at Dresden. There are also two, one owned by the Royal Astronomical Society of London and the other by the National Library of Paris, both of which are without date. Meucci's curiosity was first awakened by observing that the longitude of the stars showed that the globe must have been constructed about the year 1075. On closer examination, he found an Arabic inscription around the Antarctic Circle, which he submitted for translation to the learned orientalist, Prof. F. Lasinio. He presented a note to the Society, in a meeting which was attended by the Emperor of Brazil, in which he stated that the inscriptions were in cufic characters, and that the globe "was made by Ibrahim Ibn Said as-Sahli and his son Muhammad; the work was finished in Valenza, in the beginning of the month of Safar, in the year 473 of the Hegira (corresponding to the 22d of July, 1080)." The diameter of the globe is 209 millimetres (8·23 inches). It is composed of two hemispheres of brass, soldered together, and it gives the arrangement of stars and constellations which was adopted by Ptolemy. Among the Southern constellations, the Cup (Cratera), which should have been placed between the second and third coils of the Hydra, is wanting; all the other constellations are very well engraved. The positions of 1015 stars are given and their magnitude is well marked, inasmuch as every point, which is engraved to give the precise position of a star, is the centre of a little circle, which diminishes in diameter from the first to the sixth magnitude. The two circles of the equator and the ecliptic are divided by means of little lines into 360 degrees, every fifth degree being marked by cufic numeral figures. The zero of the equator is at its intersection with the ecliptic, in the beginning of the sign Aries. Twelve great circles of declination, lightly engraved, divide the ecliptic

into its twelve signs. Forty-seven constellations are represented, 21 of which are in the Northern hemisphere, 12 in the Zodiac, and 14 in the Southern hemisphere. A heart-shaped curved line incloses the six stars near Aquilla, which represent, upon our celestial globes, the constellation of Antinous. This constellation and that of Berenices' Hair were introduced by Tycho Brahe, in the 16th century. On this globe, as upon other Arabic globes, the figures face the observer instead of looking towards the centre of the sphere. Therefore the stars which are upon the right side of a constellation on our globes are on the left side on the Arabic globes, and *vice versa*.—*Pub. del. R. Instituto*, 1878. C.

Charlemagne's Bridge over the Rhine.—Near the close of the eighth century, Charlemagne ordered the construction, over the Rhine, of a bridge resting on twenty-eight buttresses. The bridge was struck by lightning and burnt to the level of the water. German engineers are now removing the remains of the old structure, on the Mayence side. They have already taken out fifty piles, with the lengths of five or six meters (5·468 to 6·562 yards). The wood, which is nearly eleven hundred years old, is so well preserved that it can still be used in building; the iron, which was riveted to the posts, can also be used, since it is covered only with a thin layer of rust.—*Chron. Industr.* C.

The Eden Theatre of Paris.—This building, constructed at great expense in one of the richest quarters of Paris, near the left of the new Opera House, presents a general effect of decoration surpassing in splendor all that has hitherto been undertaken in Paris or other capitals. The facade of Rue Boudreau is built of Palotte stone, of a creamy whiteness, with columns of Scotch sandstone, Venetian mosaics, huge elephants' heads, sheaves of gilded zinc, and pyramids crowning all the upper portion; the six grand lanterns of forged iron with colored glass, suspended at the height of the cornice of the third story, brilliantly illuminate the whole ground floor, the streets and the neighboring fronts. The general effect of the Indian architecture is heavy, and violates many of the rules of delicate architectural taste, but the richness of the ornamental details, especially when the building is illuminated, gives an impression of fairyland.—*Lumière Electrique*, April 14, 1883. C.